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AIR TRAFFIC CONTROLLER APTITUDE AND THE HOLLAND TYPOLOGY

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BY

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A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Education.

DEPARTMENT OF EDUCATIONAL PSYCHOLOGY

Edmonton, Alberta

FALL, 1992

ISBN 0-315-77179-8

UNIVERSITY OF ALBERTA

RELEASE FORM

TITLE OF THESIS: Air traffic controller aptitude and the Holland typology.

DEGREE: Master of Education

YEAR THIS DEGREE GRANTED: 1992

Lisa E. Vaselenak
Educational Psychology
University of Alberta

October 5, 1992

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

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DEDICATION

To my new goddaughter, born October 6th, 1992, and to my good friend, Bill Keating, who passed away on June 13th, 1992. Thankyou both for a powerful reminder of what's really important.

ABSTRACT

Although Holland's theory of vocational choice (1985a) has been extensively researched, few empirical investigations have provided information regarding the ability differences postulated to exist among the personality types. The purpose of the present study was to evaluate whether classification according to Holland's typology would differentiate individuals in terms of air traffic control aptitude. Air traffic control candidates (N=485) were classified into their Holland types, two-letter subtypes, and three-letter codes according to their scores on the Self-Directed Search (SDS). Controller aptitude was measured by the Air Traffic Control Aptitude Test (ATCAT). As hypothesized, ANOVA procedures revealed significant differences in ATCAT scores within each of the three levels of classification: the types, the two-letter subtypes, and the three-letter codes ($p<.05$). Duncan multiple range post hoc analyses (pairwise comparisons) further indicated that within each level of analysis the majority of groups were undifferentiated in controller aptitude. The applied and theoretical implications are discussed.

ACKNOWLEDGEMENTS

For all of their love, patience, and support, I want to thank my Mom and Dad, Dianne, Sharon, Glen, and the 4 short people - Mila, Laura, Michael, and my new (currently nameless) niece... what a great way to celebrate!

I would also like to express my thanks to my supervisor, Dr. George Fitzsimmons, for giving me the opportunity to work on this project, and to Dr. Fern Snart and Dr. Judy Cameron for their kindness and unflagging support. A special thanks goes to the soon to be "Dr. Travlos" for his invaluable assistance, expertise and insight throughout this task.

Finally, I want to thank my "2nd family" at the Avondale - Jennie, Marianne, Norm, Arlene, Bob, Linda, Paul and Donna - for giving me a great place to come home to.

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CHAPTER I

INTRODUCTION

The research literature regarding air traffic controllers (ATCs) can be divided into two areas. The first area encompasses investigations attempting to identify aptitudes predictive of ATC ability, hence useful as a basis for selecting among ATC applicants. The second area is comprised of investigations of the interests and personality characteristics of individuals who are amenable to the demands of controller work, and successful at it. These two areas of inquiry have largely been pursued independent of one another.

Contrary to the approach taken by investigators of ATCs, Holland's theory of vocational choice (1959, 1966, 1973, 1985a) postulates that there is an important relationship between aptitudes and personality characteristics. To paraphrase Holland (1985a): People learn to prefer certain activities over others. Participation in these activities leads to strong interests and to the development of certain abilities. The resulting pattern of interests and abilities produces a characteristic predisposition that is identifiable as a personality type. One of the main working assumptions of the theory states that in our culture, this process tends to crystallize into six model personality types, each with its own distinctive competencies. The remainder of the theory elaborates on how this information is useful in vocational guidance.

The Nature of the Problem

Although the assumption that the six personality types possess different abilities is at the heart of Holland's theory, few studies have specifically focused on it. Moreover, the few studies that have provided information regarding the types' abilities have been limited in the samples and aptitude measures employed. Empirical knowledge pertaining to Holland's assumption of ability differences among the types is therefore lacking. This type of knowledge is essential to validate Holland's six personality constructs.

The Purpose of the Study

In light of Holland's assumption that personality types differ in the aptitudes they possess, and his proposal that the types encompass personality development in our culture, it seems reasonable to speculate that the types would differ in air traffic control aptitude. The objective of the present study is to assess whether this difference exists in a sample of air traffic control candidates. If it does exist this would add to the existing knowledge regarding the differences in the types' abilities and would also bridge the two streams of air traffic control literature. Diagnosis of the type or types possessing ATC aptitude may further prove valuable in career counselling practice, and as supplemental information in the ATC selection process.

CHAPTER II

LITERATURE REVIEW

Chapter two is organized into three sections. In section one, background information pertaining to air traffic control is presented. An overview of the objectives and tasks involved is followed by a review of the literature regarding ATCs' aptitudes and personality characteristics. Section two contains a synopsis of Holland's theory of vocational choice (1959, 1966, 1973, 1985a), with an emphasis on the assumed relationship between abilities and personality types. The investigations related to this assumption are reviewed, and their general limitations are discussed. In the last section, a description of the present study is given, and the hypotheses to be tested are stated.

Air Traffic Control

The International Civil Aviation Organization (cited in Hopkin, 1988) has outlined the following five objectives for air traffic services world-wide: (1) prevention of collisions between aircraft in the air, (2) assistance in preventing collisions between aircraft moving on the apron or on the manoeuvring area of an airport, and between aircraft and obstructions on the manoeuvring area, (3) expedition and maintenance of an orderly flow of air traffic, (4) provision of information useful for the safe and efficient conduct of flights, and (5) notification of, and assistance to the appropriate organizations when an aircraft requires search and rescue aid.

In general, safety, expedience and orderliness are the essential, sometimes conflicting concerns of the air traffic controller (ATC). Along with these primary objectives, Sperandio (1978) notes that ATCs also have a series of secondary concerns to contend with. There is organizational pressure to use the shortest flight paths and to avoid holding patterns for economy of time and fuel. In terms of the crew, ATCs attempt to accommodate pilots' preferred altitudes and avoid frequent changes in flight courses and altitudes in order to minimize flight deck workload. Further, for passenger comfort, ATCs need to be aware of the location of stormy zones so unnecessary turbulence can be avoided.

In order to meet both the primary and secondary objectives of air traffic services, controllers must perform a wide variety of tasks, generally concurrently, and under considerable time pressure. These tasks vary depending on whether the aircraft are enroute, in terminal areas, or on runways; whether the methods used are procedural or based on radar information; the type of facilities and information available to the controller; and the equipment fitted in the aircraft (Hopkin, 1971). A specific task analysis of the duties involved in air traffic control is not available, but Danaher (1980) has itemized the core tasks essential to most air traffic control work as follows: observation of aircraft directly or monitoring their blips on radar or computer generated plan view displays; operating the controls for these displays; making data entries; reading and updating flight progress strips; communicating and coordinating with co-workers and pilots using disciplined communication practices and phraseology; selecting and revising plans and strategies to ensure that aircraft do not collide.

When the number of aircraft using air traffic service was considerably fewer, an ATC had a reasonable amount of time to attend to the foregoing tasks, and to meet the objectives of air traffic services. As Gilbert (1973) comments, however, the constantly increasing air traffic volume has made air traffic control an increasingly complex task. During periods of peak traffic, an ATC may have to handle up to 100 aircraft, ensuring that they meet the necessary separation standards and that they flow as efficiently as possible (Segal, 1987). Logically, the greater the number of aircraft, the greater the potential for conflict. For

ATCs this translates into both an increase in the number of problems to be solved, and an increase in the complexity of the problems to be solved. Moreover, the decrease in available airspace makes it more difficult to find acceptable solutions and put them into effect. A heavy reliance is placed therefore, on the mental skills of the modern ATC.

Aptitude Requirements

ATC screening and selection procedures have evolved parallel to the increasing complexity of the occupation. In the United States, eligibility ratings of medically qualified ATC applicants were originally based on educational level and prior aviation-related experience (Whitfield & Stammers, 1978). Experience in military ATC, or as a pilot, navigator, communications expert, radar surveillance specialist, or flight dispatcher, were given particular emphasis in the selection process. Although intuitively this type of experience appears to have validity as a predictor of ATC capability, early research revealed that this was not always the case (Cobb, 1962, Trites,1961, Trites & Cobb, 1964). With the exception of military ATC experience, all other types of aviation experience were found to be virtually worthless in predicting training outcomes and job performance.

Not surprisingly, with such unreliable selection criteria in place, the attrition rate from the ATC training academies due to failure was 30 percent (Collins, Boone & Van Deventer, 1980, 1981). Because training costs per trainee are high, a research program aimed at identifying efficient predictors of ATC ability was initiated. Four large-scale exploratory studies were conducted in which a variety of aptitude tests were administered to incoming ATC trainees on an experimental basis (Cobb, 1962, 1964; Trites, 1961; Trites & Cobb, 1964). Several measures of numerical ability, verbal ability, clerical speed and accuracy, and abstract reasoning were typically included as the predictor variables. Training academy grades, training instructors' ratings, and supervisors' ratings of actual job performance were employed as indices of ATC ability.

The results of these studies indicated that eight tests from a group of twenty-seven were significantly correlated with one or more of the measures of ATC ability. Seven of the tests referred to were actually subtests of two aptitude-measurement devices: the Psychological Corporations Differential Aptitude Test (DAT) and the California Test Bureau's Test of Mental Maturity (CTMM). The subtests of the DAT that were useful predictors of ATC ability were Space Relations, Numerical Ability, and Abstract Reasoning. The subtests of the CTMM that were useful predictors of ATC ability were Analogies, Inference, Numerical Quantity-Arithmetic, and Numerical Quantity- Coins. The eighth test that was correlated with ATC ability was the Air Traffic Problems (ATP) test, a paper and pencil test specially developed to simulate air traffic control dilemmas. Although the correlations between these measures and the measures of ATC ability rarely exceeded .40, it appeared that aptitude tests did have potential for improving the ATC selection process.

In 1964, as a result of the research efforts in this area, aptitude tests became a mandatory component of the ATC screening process in the United States. In order to avoid the potential for compromise, commercially published tests were not used. Instead tests were developed that had factor content similar to the foregoing commercial tests. Since the ATP test had been developed specifically for screening purposes and was significantly correlated with ATC ability, it was also adopted. The first ATC screening battery, referred to as the Civil Service Commission (CSC) ATC Aptitude Screening Test, was comprised of five subtests: Spatial Patterns, Computations, Abstract Reasoning and Letter Sequence, and Air Traffic Problems (See Appendix A for subtest descriptions). It was predicted that adoption of the battery would reduce attrition due to declined from 30 to 22 percent (Collins et al., 1980, 1981).

In a continuing effort to improve ATC selection procedures, several aptitude tests have been developed and evaluated for their predictive value. Boone (1980) suggested that an experimental test known as the Multiplex Controller Aptitude Test (MCAT) should be included in the ATC selection battery. Each item on the MCAT is accompanied by an air route map with various aircraft along the routes. The primary task is to predict violations of aircraft separation standards. Other items measure accuracy of table reading, spatial visualization, and arithmetic reasoning. In a sample of newly selected ATC trainees (N = 1,828), Boone (1980) found that scores on the MCAT had a stronger correlation (r = .53, p<.01) with training lab scores than any of the subtests of the current screening battery. Considering that the sample had already been selected for training based on their high scores on the CSC ATC Screening Battery, and hence the correlation is likely to be attenuated, the MCAT appears to be a strong predictor of applied ATC skills. Moreover, stepwise regression procedures indicated that a regression model comprised of the MCAT, CSC Computations, and CSC Abstract Reasoning, demonstrated a regression model comprised only of the five CSC ATC Screening Battery subtests. Collins, Schroeder, & Lendell (1991) report that the MCAT is currently among the tests used to screen ATC applicants in the United States.

In Canada, only one test is used to screen ATC applicants - the Air Traffic Controller Aptitude Test (ATCAT). Its format and content closely resemble the MCAT. For each item, there are several flight paths on a simulated radar scope, and various aircraft flying along those routes. Accompanying each radar scope is a flight information table containing the speed, altitude, and route of each aircraft. The examinee must keep track of the aircraft as they change position on the radar scope from item to item. Similar to the MCAT, half of the items require the examinee to identify potential midair collisions. Other items ask the examinee to identify distances between aircraft, compass headings of different aircraft, changes in routes, and differences in the routes of aircraft. The ATCAT is a speeded test and often examinees are unable to complete it. With the pass mark set at 70 percent, a recent report indicates that 66 percent of the applicants fail the ATCAT (Transport Canada, 1991). Reliability and validity information regarding the test value in predicting ATC ability based on its implementation in Canada, and its resemblance to the MCAT.

Personality Characteristics and Interests

The research on ATC selection has focused on identifying the aptitudes predictive of ATC ability and therefore suitable for inclusion in ATC screening batteries. To date, no assessment of personality has been included as a mandatory component of ATC screening in the United States or Canada. ATC's do however, appear to have a distinctive pattern of interests and personality characteristics that contribute to their occupational performance and satisfaction.

Smith and Hutto's (1975) survey of the interest patterns of 787 ATCs as per the Strong Vocational Interest Blank (SVIB) revealed that none of the patterns of interests established for other occupations approximate the interest patterns of journeyman ATCs. A scale of 56 items was devised that discriminated between ATCs and men-in-general (MIG). The items selected reflected ATCs above average interest in activities and occupations that are competitive, adventurous, athletic or mechanical in nature. A particular emphasis was placed on adventure-related items in the development of the ATC scale since controllers scored exceptionally high on the SVIB's Basic Interest-Adventure Scale. The items on the experimental ATC scale also reflected the ATCs less than average interest in subjects such as arts, literature and music, and occupations such as accountant, mathematician, or college professor. The group of controllers the ATC scale was validated on scored two standard deviations above MIG, thus the researchers concluded that the scale could be used to assess the likelihood that the individual, "...regardless of his abilities to master air traffic tasks, will find satisfaction in this type of work and, therefore, persist in it" (Smith & Hutto, 1975, p.877).

Building upon the foregoing study, Musolino and Hershenson (1977) hypothesized that controllers' interest in adventurous occupations and activities is an indication of an important facet of their personalities: a requirement or preference for a high degree of sensation-stimulation. Subsequent to having twelve personnel specialists and psychologists rank-order ten occupations according to the degree of sensation-seeking involved in each, 100 male ATCs (ranked second in sensation-seeking) were compared with 78 male civil service employees (ranked ninth in sensation seeking) on Zuckerman's Sensation Seeking Scale (SSS). ATCs exceeded the mean score of civil and Adventure, Boredom Susceptibility, Disinhibition, Experience Seeking and General. The t-values were all significant beyond the .001 level. The possibility that sensation seeking may arise from years of being an ATC rather than from the type of person initially attracted to controller work was also examined by calculating the correlation between the SSS scores and length of service as an ATC. The correlation was not significant, suggesting that sensation seeking, as a personality trait, may lead individuals to seek out high sensation occupations such as air traffic control.

Considering the adventurous, sensation seeking tendencies of ATCs it is not surprising that three large-scale surveys of ATCs reveal that the predominant source of job satisfaction reported was the challenging, fast-paced and constantly changing nature of air traffic work (Singer & Rutenfranz, 1971; Smith, 1973; Smith, Cobb & Collins, 1972). While reviews of the physiological and biochemical studies of ATC stress indicate that controllers undergo periods of intensive effort (Crump, 1979; Hopkin, 1980) the subjective reports of ATCs do not suggest a dislike of controlling peak-volume air traffic. When dissatisfaction was expressed with actual job tasks, it was not related to the pressures of excessive traffic, but to the tedious non-traffic control duties required of them (Smith, 1973; Smith, Cobb & Collins, 1972). In fact, when asked an open-ended question regarding what they particularly disliked about their job, ATCs mentioned the stress of the workload least frequently, and frustrations with management most frequently (Singer & Rutenfranz, 1971). Mohler (1983) has remarked that it may be the boredom of air traffic underflow, and disagreements with management that engender stress for ATCs.

Controller's attitudes toward their workload may have significant, far reaching implications. As Hopkin (1980) has noted, if handling heavy air traffic efficiently and safely is a main source of job satisfaction and interest, changes made to reduce workload may result in boredom, and hence a general reduction in job satisfaction. A recent study of ATC operating irregularities (Stager & Hameluck, 1990) is suggestive of just how important it is for the ATC to be challenged by his or her work. An analysis of 301 operating irregularities indicated that out of the 265 operating irregularities ATCs were responsible for, 80 percent occurred under conditions of low or moderate levels of workload. Further, attention and judgement errors were cited as the cause of the irregularities in over 70 percent of the cases. The results are particularly salient with the trend in automation of

ATC tasks. Although automation is intended to reduce demands on ATCs, it could potentially contribute to operating error. Ergonomists need to consider that ATCs appear to perform better under, and even prefer high task load conditions.

The ATC's preference for high levels of stimulation is complemented by what appears to be a composed, relatively anxiety-resistant disposition. A recent study of 1,790 ATC trainees (Collins, Schroeder & Lendell, 1991) found that ATC students had significantly lower state (current level) and trait (proneness) levels of anxiety than college students and military recruits. Despite the narrower distribution of anxiety scores among ATC trainees, an index based on a combination of state and trait anxiety scores was significantly related to overall training results: higher categories of anxiety scores yielded higher percentages of academy failures and withdrawals. The investigators also report that anxiety scores are not correlated with MCAT scores. Having screened-in only high scorers on the MCAT, however, precludes this type of conclusion due to the attenuation in correlation that would result from the restricted range in MCAT scores. The study does indicate, however, that the original self-selection evidenced by the low anxiety scores among ATC entrants is further reinforced by the higher training failure rates of those with higher levels of anxiety. As the investigators remark, "... those who become ATCs comprise an occupational group that appears to have a high tolerance for circumstances that might produce anxiety" (Collins, et al., 1991, p. 240).

An earlier examination of the personality structure of ATCs indicates that anxiety tolerance may even play a central role in the personality of successful ATCs. Karson and O'Dell (1974) factor analyzed the 16 Personality Factor Questionnaire (16PF) responses of 11,047 ATCs and found that the items cluster in the same manner as they do for the general population. However, rather than the Invia-versus-Exvia factor accounting for most of the 16PF response variance, as it does in the general population, the Dynamic Integration-versus-Anxiety factor accounted for the greater portion of the variance in the ATC's 16PF scores.

The role of compulsivity in the ATC personality was also evident in the Karson and O'Dell (1974) study. Because the sample size was unusually large, ATCs differed significantly from the general population in 14 of the 16 personality factors. To render these results more interpretable, the investigators used a technique whereby a computation of the proportion of variance attributable to each mean difference is calculated. Compulsivity accounted for 10 percent of the variance, while the remaining mean differences were unable to account for more than 3 percent of the variance. Interestingly, the compulsivity scale loaded highest on the Dynamic Integration-versus-Anxiety factor, the second-order factor that accounted for most of the variance in ATCs' 16PF responses. The investigators note that the primacy of the Dynamic Integration versus Anxiety factor in the personality of ATCs undoubtedly reflects the fact that " ... emotional control and absence of free floating anxiety is so essential to ATC work, along with the presence of compulsive defense mechanisms required for this responsible work" (Karson & O'Dell, 1974, p. 1007).

In summary, it appears that ATCs possess a constellation of interests and personality characteristics well-suited to the demands of their occupation. ATC students with low levels of anxiety are able to meet controller training requirements, and in turn, apply their skills in the field without being overwhelmed by the stress and responsibility of this type of work. In fact, successful ATCs not only tolerate, but respond well to the high degree of sensation inherent to air traffic work. Most of their occupational satisfaction is derived from the opportunity to exercise their skills in challenging air traffic situations. Fortunately ATCs also have the greater than average compulsivity important in occupations where the safety of others depends on one's performance.

Holland's Theory: A Synopsis

The literature indicates that ATC's share certain aptitudes, interests, and personality traits. These areas of investigation have been pursued in isolation from one another, and there has been some suggestion in the ATC literature that these characteristics are unrelated (Collins et al., 1991; Smith & Hutto, 1975). In his theory of vocational choice, Holland (1959, 1966, 1973, 1985a) argues, however, that there is an integral relationship among aptitudes, interests, and personality, which is functional in terms of vocational counselling.

The primary intention of Holland's theory is to provide a parsimonious account of the personal and environmental characteristics that lead to satisfying career decisions and occupational achievement. This information can then be applied by vocational counsellors to assist people in choosing satisfying jobs they will excel at. Central to the theory is the notion that choice of vocation is more than an expression of interest, it is a fundamental expression of personality. A simplified interactionist formula for personality development is offered to provide the foundation for this concept. Biological endowment is credited with providing the child with a certain range of physical and psychological potentials, while parents tend to provide environmental opportunities in keeping with their own activity preferences. The child's natural predisposition and early environmental experiences lead to preferences for some types of activities and aversions to others. These preferences develop into increasingly differentiated interests that are satisfying, and rewarded by those around them. With pursuit of these interests, specialized competencies are developed, and unexercised aptitudes atrophy. A corollary of these developments is the rise of a value system related to these interests and skills. The result of the increasing delineation of preferred activities, interests, competencies, and values is the development of a disposition characterized by particular behavioral repertoires and coping strategies, perceptions of the self and environment, task and reward preferences, skills and achievements, and related personality traits.

The direction of development is typically, then, from activities, interests and competencies, to personality. Once these dispositions are fairly well-defined, people search for educational and occupational environments that encourage them to exercise their skills and aptitudes, express their attitudes and values, and take on agreeable problems and roles. Although one's personality type is not immutable, according to the theory stability is the norm.

Holland assumes that in our culture the developmental process outlined tends to result in six common types: Realistic (R), Investigative (I), Artistic (A), Social (S), Enterprising (E), and Conventional (C). While these six types resemble the six factors Guilford, Christensen, Bond & Sutton (1954) arrived at in their large-scale factor analysis of human interests, Holland is proposing that his typology accounts for more than clusters of interests. The typology represents six model personality types, each with distinctive abilities, interests, values, and personality attributes (see Appendix B).

An individual's personality type may be assessed qualitatively or quantitatively. The qualitative methods involve assessing the type of occupation or educational training the person is currently engaged in, or the type of vocation or educational training preferred. The quantitative methods assess the person's resemblance to the types according to his or her scores on the scales of the Vocational Preference Inventory

(Holland, 1985b), the Self-Directed Search, (Holland, 1986a), or the Strong- Campbell Interest Inventory (Campbell & Hansen, 1985). To avoid an oversimplified analysis of personality, an individual's resemblance to each of the six types can be rank-ordered, allowing for 720 different personality patterns. For research purposes, an individual's highest score (type), two highest scores (two-letter subtype), or three highest scores (three-letter code or Holland Code) are typically employed.

According to the theory, educational and occupational environments can be similarly classified using the same six category system since environments require, encourage and reward particular competencies and characteristics. Assessment of the frequencies of the different personality types in an environment is said to indicate the type of environment since individuals search for, and remain in, environments that are satisfying and rewarding. Numerous occupations (Holland, 1986b; Gottfredson, Holland & Ogawa, 1982) and educational environments (Astin, 1963, 1964, 1965; Astin & Holland, 1961) have been classified to aid people in selecting educational and vocational routes. The assumption is that a pairing of one's personality type with a congruent environmental type will lead to vocational or educational achievement, satisfaction, and stability.

To strengthen the precision and hence the utility of the typology, Holland, Whitney, Cole & Richards (cited in Holland, 1973, 1985a) have specified the interrelationships among the six categories using a hexagonal model (Figure 1). The psychological similarities among the types are assumed to be inversely proportional to the distances among them. The shorter the distance between any two types, the greater their resemblance. For example, types who are adjacent on the hexagon would tend to share similar competencies, while types who are opposite each other on the hexagon would tend to have contrasting competencies. The model can be used to assess congruence and consistency, two of the theory's secondary constructs (see Appendix C for definitions of the secondary constructs). The common theme among the secondary constructs is that a focused, clearly defined personality type, coupled with a congruent environment is optimal for educational or occupational satisfaction, achievement and stability.

Investigations of Types' Abilities

To date, over 400 investigations of Holland's theory (1985a) have been conducted. Although it is the cornerstone of the theory, relatively few studies have

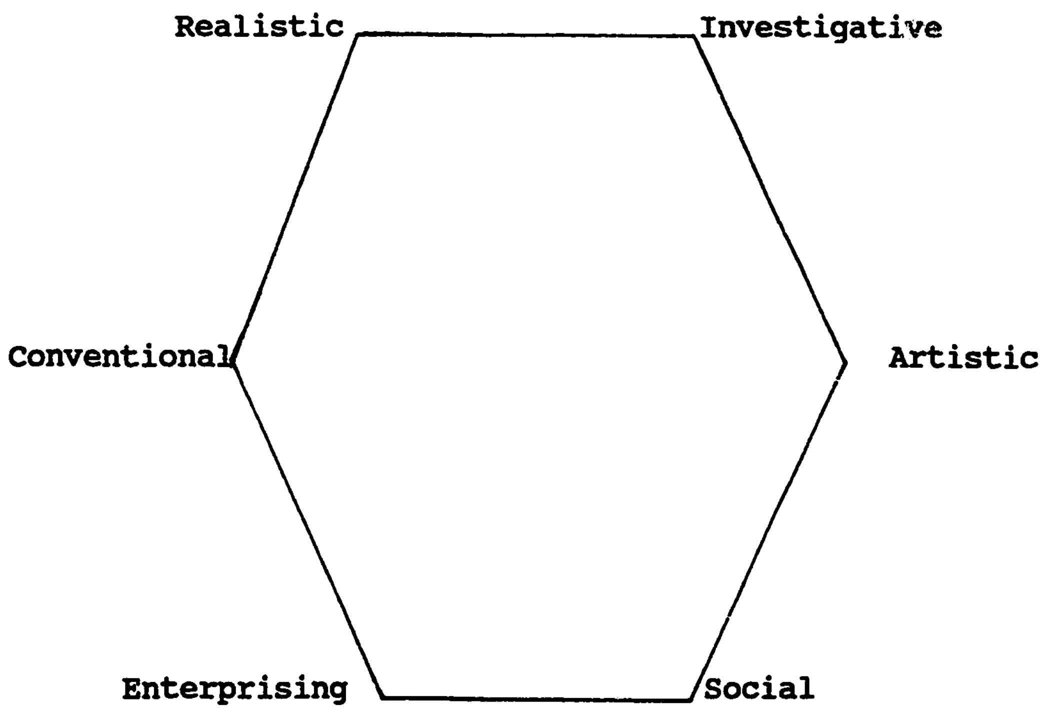

Figure 1. Hexagonal model of the interrelationship among Holland's six types.

focused on the assumption that the personality types differ in the abilities they possess. A review of these studies, as well as studies that inadvertently report results that bear on this assumption, provides a limited amount of information regarding the abilities of each of the types. Only studies that report aptitudes concurrently related to the types will be reviewed.

In the earliest attempt to explore how the types differ, Holland (1962) assessed two large samples (N = 1,177 and 994) of National Merit Finalists. Measures of ability were included in a large battery of dependent measures. The study was exploratory in nature, so specific hypotheses were not stated. Correlational analyses revealed the following trends in Scholastic Aptitude Test (SAT) results: R-types scored low on verbal, I-types scored high on math, A-types scored low on math and high on verbal, S-types scored low on math, E-types scored low on verbal and math, and C-types scored low on verbal. Although these correlations were significant ($p<.05$), none exceeded .22. Chi-square analyses of categories of artistic and scientific ability also revealed significant differences among the types. R- and I-types tended to score high on scientific ability and low on artistic ability, while A-, E- and S-types tended to score high on artistic ability and low on scientific ability. Post-hoc analyses are not reported, thus the degree and nature of the overlap in aptitude among the types cannot be determined. In general, Holland (1962) concludes that the different types have significantly different abilities, usually congruent with the type formulations.

In a subsequent large-scale study of college students (N = 3,147), Holland (1968) set out to test specific hypotheses derived from the type formulations: R-types will score highest on technical competency, I-types will score highest on scientific competency, S-types will score highest on social and educational competencies, E-types will score highest on leadership and sales competency, C-types will score highest on business and clerical competency. Given a list of various activities, subjects were asked to check off the activities they were competent at. These competencies were then categorized by three judges into the foregoing six competency categories. Although specific post-hoc analyses were absent,the results of F-tests across single-letter types, two-letter subtypes, and three-letter subtypes indicated that across all three levels of analysis, there were significant differences ($p<.05$), generally in the predicted directions. For instance, R-types scored highest on technical competencies among the single-letter types, RI subtypes scored highest on scientific competency among the R-dominant two-letter subtypes, and RIA codes scored highest on artistic competency among the R-dominant three-letter codes. Holland (1985) describes the results of the Holland (1968) study as the most valuable of the early studies because the sample was large enough to test the three-letter codes, and unlike Holland (1962) the sample is not an elite group of scholarship finalists.

Kelso, Holland and Gottfredson (1977) have provided information regarding how the nine aptitudes measured by the Armed Services Vocational Aptitude Battery (ASVAB) are related to the Holland types. On the basis of Holland's (1973) type formulations, the following nine predictions were made: Coding Speed should correlate most highly with C-scores; Word Knowledge and Arithmetic Reasoning should correlate most highly with I-scores; Tool Knowledge, Mechanical Comprehension, Shop Information, Automotive Information, and Electronic Information should correlate most highly with R-scores; Space Perception should correlate most highly with A-scores. Seven of these predictions were supported, but only three of the correlations reached significance: Coding Speed correlated most highly with C-scores ($r = .15$, $p<.05$);

Word Knowledge and Arithmetic Reasoning correlated most highly with I-scores ($r = .24$ and $.27$, $p<.01$). Interestingly, the two aptitudes that did not conform to the predictions (Space Perception and Mechanical Comprehension) were also most highly correlated with I-scores ($r = .35$ and $.29$, $p<.01$). The investigators note that they failed to predict that the I-scores would have the largest number of significant correlations with the aptitude variables, but explain that it is not surprising since the I-type is related to high intelligence and thus would be related to a broad range of aptitudes.

Independent research further supports the notion that I-types are superior in terms of general academic aptitude. In a predictive study of the occupational constancy of 530 male senior college students, Elton and Rose (1970) report the differences in the entrance American College Test (ACT)- composite scores among the six Holland types. Although it was not the purpose of the study, univariate F-tests revealed a significant difference among the types ($p<.05$) with the I-types scoring the highest and the S-types scoring the lowest. No post hoc analyses were reported. Schneider and Overton (1983) conducted a similar analysis in their predictive study of the academic achievement of 254 male and 282 female college students. One-way analysis of variance indicated that SAT-total scores were significantly different across Holland's types for both males and females ($p<.001$). Duncan multiple range post hoc analyses revealed that male I- and A-types had higher SAT-total scores than male S- and E-types, while female I-types had higher SAT-total scores than the remaining 5 types.

The type descriptions offered by Holland (1959, 1966, 1973, 1985a) suggest that the types should also vary in terms of the abilities tapped by the two subtests of the SAT - Verbal and Mathematical. Specifically, Yonge and Regan (1975) have interpreted Holland's (1973) formulations as indicating that I- and C-types should possess elevated mathematical aptitude, A-types should possess elevated verbal aptitude, and E- and S-types should possess low mathematical aptitude. Their study of 626 college males found, however, that the types only differed significantly ($p<.05$) in SAT-Math. No post hoc analyses were reported, but the C- and I-types did score highest and second highest, respectively, in math, while the E-types scored the lowest.

Turner and Hibbs (1977) employ a different methodology to investigate whether three specific patterns of SAT subtest scores are related to different Holland types. A criterion of 80 points between the SAT verbal and math scores was set to form a group of high verbal- low math aptitude and a group of low verbal- high math aptitude. For differences of ten points or less a verbal-equals-math aptitude group was formed. Analysis of variance indicated that for both genders, a significant difference in Artistic scores existed, with the high verbal-low math aptitude group scoring the highest. For the males, there was also a significant difference in the Social scores, again with the high verbal- low math aptitude group scoring the highest. Thus, when high verbal aptitude is accompanied by low math aptitude, a relationship is found with Artistic and Social inclinations.

Limitations of the Investigations

While a review of the related literature indicates that studies have provided some information regarding the types' abilities and their differences in abilities, there appears to be a need for further research due to limitations in the aptitude measures employed and the samples assessed. In terms of the aptitude measures, there are two limitations. First, the use of self-reported estimates of competency as the dependent measure, as in the Holland (1968) study, is problematic since studies have found significant differences between the self-estimates and objective measures of several types of aptitudes (Booth & Laurin-

Dumas, 1980; Regan, Gosselink, Hubsch & Ulsch, 1975).

In support of the use of self-reported competencies, Holland (1985a) refers to the Kelso et al. (1977) study where canonical correlations indicated that self-ratings of ability and self-reports of competencies on the Self-Directed Search (SDS) accounted for more of the variance in ASVAB scores (an objective aptitude measure) than any of the other sets of SDS scales. The variance accounted for was occasionally as much as one-third of the total variance in ASVAB scores. Kelso et al. (1977) conclude that their results support the notion that self-reports of competency and ability are positively related to objective assessment of aptitudes. The degree of relationship does not appear large enough, however, to comfortably abandon objective aptitude measures in favour of self-reported measures when investigating the relationship between personality type and aptitudes.

The second limitation pertaining to the aptitudes measured in the studies reviewed is the lack of diversity. While the type formulations propose that a variety of competency differences exist among the types, independent research (Elton & Rose, 1970; Schneider & Overton, 1983; Turner & Hibbs, 1977; Yonge & Regan, 1975) has only provided information regarding the differences in the types' academic aptitudes (eg., SAT or ACT scores). While this type of information is accessible due to the entrance requirements of many academic institutions, the focus on this type of aptitude limits our knowledge of other aptitudes that may be differentially distributed among the types. Theoretically, a researcher should be able to explore how the types differ in terms of any objectively measurable aptitude since Holland (1985a) claims that his typology encompasses the common ways abilities and personality coincide in our culture.

The studies reviewed also have limitations regarding the types of samples assessed. Holland (1973, 1985a) has noted that the various assumptions of the theory need to be tested across diverse samples. While this recommendation appears to have been followed in validation studies concerned with other characteristics of the types, the majority of studies reporting information regarding the types' aptitudes have been undertaken within samples of elite high school students or college students. Aside from the issue of external validity, the use of such samples can also pose a problem for analysis of the results when the SAT or ACT is the aptitude measure employed. For instance, Holland (1962) does not report the distribution of the SAT scores for his sample of national college scholarship finalists, but it must be severely restricted in range since Nichols & Holland (1963) follow-up the same sample in a study pertaining to high aptitude subjects, as determined by their SAT scores. The result of the use of the same sample in the earlier study (Holland, 1962) would be an attenuation of the correlation between the scores on the type-scales and the SAT scores. The extent of the true relationship would thus be unknown.

Results from independent studies reporting the SAT differences among the Holland types in college samples (Elton & Rose, 1970; Schneider & Overton, 1983; Yonge & Regan, 1975) would have a lesser degree of the same problem due to minimum college entrance requirements for SAT scores. None of the studies reviewed report the distribution characteristics of the aptitude being investigated although a normal distribution is one of the assumptions underlying correlational analyses and analysis of variance. Furthermore, significant correlations and significant group differences are difficult to uncover without sufficient variability in the data. Perhaps the studies reviewed would have found stronger correlations or a larger number of group differences if the range of aptitude scores was less restricted.

In summary, a review of the literature indicates a general need for further tests of the assumption that

Holland's types possess different abilities. More specifically, to expand our knowledge of the types' abilities, investigations need to be conducted using objective aptitude measures, other than SAT or ACT scores. With regards to the samples utilized, the assumption needs to be tested in samples other than college students, and in samples where the aptitude in question is not truncated due to selection criteria.

Proposed Study and Research Hypotheses

The present study seeks to add to the knowledge regarding the differences in ability among the Holland types. The general limitations of the previous studies in this area will be addressed by employing a sample of air traffic control candidates and an objective measure of ATC aptitude. Following their classification into types, two-letter subtypes, and three-letter codes, the following three hypotheses will be tested:

1. The Holland types will differ in ATC aptitude.
2. The Holland two-letter subtypes will differ in ATC aptitude.
3. The Holland three-letter codes will differ in ATC aptitude.

CHAPTER III

METHODS AND PROCEDURES

The Sample

Data for the study was gathered in conjunction with Transport Canada's regularly scheduled ATC aptitude testing sessions. To be eligible for ATC aptitude screening, an applicant must be 18 years of age or older, a high school graduate, and a Canadian citizen. A total of 511 ATC candidates meeting the foregoing criteria were asked to participate in the study. Eight candidates declined, and the data from a further 18 candidates was incomplete. The final sample (N=485) was comprised of 104 females and 381 males. The age range for the females was from 18 to 44 (M = 27.22, SD = 5.90), while for the males it was from 18 to 57 (M = 28.76, SD = 6.30). Table 1 provides the frequencies for the various educational levels reported by the participants. The mode for both males and females was a Grade 12 education.

Instruments

Two instruments were employed in the study: (1) the Canadian edition of the Self-Directed Search (SDS), and (2) the Air Traffic Controller Aptitude Test (ATCAT) - form E-250 A2.

Table 1

Educational Level Frequencies for Male and Female Air Traffic Control Candidates

		Males (n=381)		Females (n=104)	
Education		f	%	f	%
Grade	12	156	40.5	37	35.2
College	1 yr	42	10.9	23	21.9
	2 yrs	42	10.9	16	15.2
	3 yrs	13	3.4	2	1.9
	4 yrs	11	2.9	3	2.9
University	1 yr	26	6.9	5	4.8
	2 yrs	29	7.5	6	5.7
	3 yrs	21	5.5	4	3.8
	4 yrs	40	10.4	8	7.6
	Graduate	1	.3	0	-

Self-Directed Search (SDS)

The Canadian edition of the SDS (Holland, 1986a) was used to obtain candidates' scores on the six personality types postulated in Holland's theory of careers (1985a). Typically, the SDS is self-administered, self-scored, and self-interpreted for purposes of vocational guidance. Subsequent to these three steps, the Occupations Finder (Holland, 1986b) can be used to find occupational environments congruent to the individual's personality characteristics. The idea is to get the optimal "fit" between person and occupational environment.

The SDS booklet is divided into four sections corresponding to the inventory's four subscales: Activities, Competencies, Occupations, and Self-Estimates. Within each of the subscale sections, there is an equal number of items from the six summary scales: Realistic, Investigative, Artistic, Social, Enterprising, and Conventional. The higher the number of items positively endorsed on a summary scale, the greater the individual's resemblance to that particular personality type. An individual's highest summary scale score indicates his/ her personality "type", while rank ordering an individual's six summary scale scores from highest to lowest yields a comprehensive personality "pattern". In the present study, whenever ties existed in the scale scores of a participant (eg. a participant did not differentiate herself or himself as a type, two-letter subtype, or three-letter code), the data from this participant was excluded from the relevant analysis.

Holland (1985c) reports two indices of reliability for the SDS: retest correlations and internal consistency (alpha). For the adult sample (19 to 74 years of age), the six summary scales (R, I, A, S, E, C) had retest correlations ranging from .83 to .93, while their internal consistency coefficients ranged from .86 to .92. The internal consistency of the R, I, A, S, E, and C items within the Activities, Competencies, and Occupations subscales, separately, ranged from .73 to .92. Correlations between the corresponding self-estimates of ability for each SDS summary scale tended to be quite low, ranging from .27 to .85. For the purposes of the present study, participants were asked to omit the Self-Estimates subscale when completing the SDS. In total, then, participants were required to respond to 216 items. A maximum score of 36 was possible on each of the summary scales.

As an estimate of concurrent validity, Holland (1985c) reports the "hit rate" of the SDS with regard to occupations currently held and future career aspirations. For the adult sample (19 to 74 years of age), the hit rate ranged from 58 to 64 percent. That is, on average, 60 percent of the sample achieved Holland types that were congruent with the one-letter Holland code for their current occupations or for the careers they aspired toward. Comparatively, this is a respectable hit rate since a review of concurrent and predictive studies indicates that the hit rate for other interest inventories ranges from 40 to 55 percent (Holland and Rayman, 1986).

Air Traffic Controller Aptitude Test (ATCAT)- E-250 A2

The ATC Aptitude Test is used across Canada to screen applicants for training as air traffic controllers. It is designed to assess the accuracy with which an examinee can answer questions regarding air traffic presented pictorially on a simulated radar scope. For example, given the altitude, speed, and route of several aircraft in a flight information table, a typical test item requires the examinee to determine which of several aircraft on the radar scope will violate the required separation standard. Other items provide similar information tables and require the examinee to estimate the travel times and distances travelled by specified aircraft.

The ATC Aptitude Test booklet is divided into two parts. Part One provides the operational rules and separation standards for aircraft. These include a specific definition of what is considered to be aircraft "conflict". Knowledge of this definition is essential to accurately answer many of the test items. Part One also contains a familiarization exercise which previews the types of information the examinee must be able to integrate in order to successfully respond to the test items. Examinees are given eight minutes to study and practice applying the information in this section, prior to writing the actual test.

Part Two, the test portion of the booklet is comprised of 50 multiple choice items . Examinees are given 35 minutes to answer as many of the items as possible. The examinee's total score is the number of items responded to correctly out of 50. There is no deduction for items responded to incorrectly. The pass mark set by Transport Canada is 35 out of 50 marks, or 70%. Reliability and validity information for the ATCAT are unavailable.

Procedure

To gather data for the study, 13 ATC aptitude testing sessions were attended. At the beginning of each session candidates were briefed regarding the completion of the two instruments as a part of a research project. They were informed that they were free to leave should they experience any physical or psychological discomfort during the test session.

The order in which the tests were administered was counterbalanced such that in six of the sessions the ATC Aptitude Test was written first and in seven of the sessions the SDS was written first. Both instruments were administered in all of the sessions.

Prior to distributing the SDS booklets, the candidates were explicitly informed that their results on the SDS would not affect whether they would be selected for an interview or for ATC training. They were told that their SDS results would be anonymous and confidential, and that Transport Canada Personnel would not be reviewing them. They were instructed to bear this in mind and to respond to the SDS items naturally.

Since the SDS is designed for self-administration, only a brief overview of its contents was given. Three trained persons supervised each testing session and candidates were instructed to raise their hands should they have difficulty completing the SDS. To keep the testing sessions as brief as possible, candidates were told to disregard the scoring sections of the SDS. No session exceeded 110 minutes.

The results of the SDS were optically scored and read directly into a data file. The results of the ATC Aptitude Test and basic demographic information regarding candidates' age, gender, and education were accessed via Transport Canada's computerized data bank and input into the existing data file.

Statistical Analysis

Each of the analyses was conducted using analysis of variance (ANOVA) procedures for unequal cell sizes (Milliken & Johnson, 1984). Tests of homogeneous variance were conducted to ensure that this assumption was not violated (Kirk, 1982). The alpha level for rejection of the null hypothesis was set at .05 for all statistical comparisons. Duncan Multiple Range post hoc analyses (pairwise comparisons) were conducted to locate and identify the nature of any statistically significant differences.

Limitations and Delimitations of the Study

1. The unavailability of information regarding the ATCAT required that two assumptions be made. First, it was assumed that the ATCAT measures an aptitude related to successful performance as an ATC. Second, it was assumed that the ATCAT had item homogeneity and measured ATC aptitude with relatively little measurement error.
2. The use of a convenience sample has two implications. First, the results may not be generalizable to random samples of Holland types since only persons already interested in becoming ATCs were sampled. A replication study employing a random sample is therefore required. Second, because the sample was comprised of ATC candidates they may have disregarded the instructions and responded to the SDS in a manner they believed would facilitate their selection. In this case the results would be contaminated by an inaccurate assessment of personality. Falsification of personality questionnaires is a common dilemma in psychological

testing (Cronbach, 1970).

3. Data collection had to be terminated due to Transport Canada's implementation of a longer version of the ATCAT. This is problematic for two reasons. First, categorization by type and sex, plus omissions due to tied scores, greatly reduces the usable portion of the sample and the sizes of the cells analyzed. Large samples are thus required. Second, some of the two- and three-letter subtypes were not represented, or had such a low frequency they could not be analyzed. A survey of the subtypes found in college samples (N = 1,378) indicates, however, that certain subtypes are rare regardless of the sample size (Holland, 1985c).

CHAPTER IV

RESULTS

The purpose of the study was to investigate whether ATC aptitude varied significantly within 3 cross-sections of the sample data: (1) Holland one-letter codes or "types", (2) Holland two-letter subtypes, and (3) Holland three-letter codes. Following the description of the ATCAT score distribution, the results are presented in the above order. The intent is to progress from the more general single-letter types to the more specific information provided by the three-letter codes to determine whether there is a trend in the types and subtypes possessing ATC aptitude.

Controller Aptitude

ATCAT scores are given as a single score out of 50 marks. The results ranged from 12 (24%) to 49 (98%). The mean for the sample was 34.23 (68.5%), with a standard deviation of 7.60. With the pass mark set at 35 marks, 53% of the candidates sampled passed the exam.

Holland Types

The frequency of occurence of the 6 Holland Types, the 2-letter subtypes, and the 3-letter codes are given in Table 2. For the total sample, and for the males only, the pattern of the most common to least common-

Table 2

SDS Summary Code Frequencies for ATC Candidates

1-letter	2-letter	3-letter	Males (n=381) f	Males (n=381) %	Females (n=104) f	Females (n=104) %	Total (n=485) f	Total (n=485) %
R			116	30.4	4	3.8	120	24.7
	RI		50	13.1	2	1.9	52	10.7
		RIA	2	.5	0	-	2	.4
		RIS	8	2.1	0	-	8	1.6
		RIE	22	5.8	0	-	22	4.5
		RIC	7	1.8	1	.9	8	1.6
	RA		5	1.3	0	-	5	1.0
		RAI	2	5	0	-	2	.4
		RAS	1	.3	0	-	1	.2
		RAE	1	.3	0	-	1	.2
		RAC	1	.3	0	-	1	.2
	RS		15	3.9	0	-	15	3.1
		RSI	5	1.3	0	-	5	1.0
		RSA	1	.3	0	-	1	.2
		RSE	5	1.3	0	-	5	1.0
		RSC	3	.8	0	-	3	.6
	RE		25	6.6	0	-	25	5.2
		REI	7	1.8	0	-	7	1.4
		REA	1	.3	0	-	1	.2
		RES	6	1.6	0	-	6	1.2
		REC	7	1.8	0	-	7	1.4
	RC		7	1.8	0	-	7	1.4
		RCI	4	1.0	0	-	4	.8
		RCE	1	.3	0	-	1	.2
I			87	22.8	19	18.3	106	21.8
	IR		35	9.2	3	2.9	38	7.8
		IRA	3	.8	0	-	3	.6
		IRS	7	1.8	1	.9	8	1.6
		IRE	13	3.4	0	-	13	2.7
		IRC	10	2.6	2	1.9	12	2.5
	IA		6	1.6	2	1.9	8	1.6
		IAR	2	.5	0	-	2	.4
		IAS	1	.3	1	.9	2	.4
		IAE	1	.3	0	-	1	.2
		IAC	1	.3	1	.9	2	.4
	IS		7	1.8	5	4.8	12	2.5
		ISR	2	.5	1	.9	3	.6
		ISA	0	-	1	.9	1	.2
		ISE	1	.3	0	-	1	.2
		ISC	1	.3	2	1.9	3	.6
	IE		13	3.4	2	1.9	15	3.1

1-letter	2-letter	3-letter	Males f	Males %	Females f	Females %	Total f	Total %
		IER	7	1.8	0	-	7	1.4
		IEA	1	.3	1	.9	2	.4
		IES	2	.5	0	-	2	.4
		IEC	2	.5	1	.9	3	.6
	IC		16	4.2	2	1.9	18	3.7
		ICR	7	1.8	1	.9	8	1.6
		ICS	1	.3	0	-	1	.2
		ICE	6	1.6	1	.9	7	1.4
A			12	3.1	9	8.7	21	4.3
	AR		2	.5	4	3.8	6	1.2
		ARI	0	-	1	.9	1	.2
		ARS	1	.3	0	-	1	.2
		ARC	0	-	3	2.9	3	.6
	AI		1	.3	4	3.8	5	1.0
		AIR	1	.3	2	1.9	3	.6
		AIS	0	-	1	.9	1	.2
	AS		3	.8	1	.9	4	.8
		ASR	1	.3	0	-	1	.2
		ASI	0	-	1	.9	1	.2
	AE		3	.8	0	-	3	.6
		AER	2	.5	0	-	2	.4
		AES	1	.3	0	-	1	.2
S			32	8.4	25	24.0	57	11.8
	SR		5	1.3	2	1.9	7	1.4
		SRI	2	.5	0	-	2	.4
		SRA	0	-	1	.9	1	.2
		SRE	3	.8	0	-	3	.6
	SI		4	1.0	11	10.6	15	3.1
		SIA	1	.3	1	.9	2	.4
		SIE	2	.5	7	6.7	9	1.9
		SIC	0	-	1	.9	1	.2
	SA		6	1.6	3	2.9	9	1.9
		SAI	3	.8	1	.9	4	.8
		SAE	2	.5	2	1.9	4	.8
	SE		12	3.1	2	1.9	14	2.9
		SER	1	.3	0	-	1	.2
		SEI	4	1.0	0	-	4	.8
		SEA	1	.3	0	-	1	.2
	SC		5	1.3	5	4.8	10	2.1
		SCI	0	-	2	1.9	2	.4
		SCE	3	.8	2	1.9	5	1.0
E			70	18.4	21	20.2	91	18.8
	ER		21	5.5	0	-	21	4.3
		ERI	9	2.4	0	-	9	1.9
		ERS	3	.8	0	-	3	.6

1-letter	2-letter	3-letter	Males f	Males %	Females f	Females %	Total f	Total %
		ERC	6	1.6	0	-	6	1.2
	EI		11	2.9	7	6.7	18	3.7
		EIR	4	1.0	0	-	4	.8
		EIA	0	-	1	.9	1	.2
		EIS	2	.5	0	-	2	.4
		EIC	3	.8	3	2.9	6	1.2
	EA		7	1.8	2	1.9	9	1.9
		EAR	1	.3	0	-	1	.2
		EAI	3	.8	0	-	3	.6
		EAS	2	.5	1	.9	3	.6
	ES		9	2.4	4	3.8	13	2.7
		ESR	6	1.6	1	.9	7	1.4
		ESI	1	.3	1	.9	2	.4
		ESC	0	-	2	1.9	2	.4
	EC		15	3.9	6	5.8	21	4.3
		ECR	8	2.1	0	-	8	1.6
		ECI	2	.5	2	1.9	4	.8
		ECS	3	.8	3	2.9	6	1.2
C			29	7.6	17	16.3	46	9.5
	CR		8	2.1	1	.9	9	1.9
		CRI	2	.5	0	-	2	.4
		CRS	1	.3	1	.9	2	.4
		CRE	5	1.3	0	-	5	1.0
	CI		11	2.9	3	2.9	14	2.9
		CIR	0	-	1	.9	1	.2
		CIA	1	.3	0	-	1	.2
		CIS	3	.8	1	.9	4	.8
		CIE	6	1.6	0	-	6	1.2
	CA		0	-	1	.9	1	.2
	CS		2	.5	5	4.8	7	1.4
		CSI	2	.5	2	1.9	4	.8
		CSE	0	-	1	.9	1	.2
	CE		4	1.0	6	5.8	10	2.1
		CER	1	.3	0	-	1	.2
		CEI	1	.3	0	-	1	.2
		CEA	0	-	2	1.9	2	.4
		CES	0	-	2	1.9	2	.4
Ties			35	9.2	9	8.7	44	9.1
	Ties		38	10.0	12	11.5	50	10.3
		Ties	45	11.8	15	14.4	60	12.4

Note. R = Realistic; I = Investigative; A = Artistic; S = Social; E = Enterprising; C = Conventional; Ties = Any combination of tied types. Frequencies are denoted by (f).

occurring types was: R I E S C A. For the females, the pattern was different: S E I C A R. As indicated at the end of Table 2, data from 44 participants had to be dropped from the analysis of the single-letter types because they tied on the first 2 letters of their profiles. In these cases, a Holland type could not be defined. The omission of this data left 91% (n = 441) of the sample intact for analysis.

The ATCAT means and standard deviations for each type are presented in Table 3. The R-types achieved the highest mean ATCAT score across the entire sample (M = 36.14, SD = 6.89), and also within the female group(M = 37.75, SD = 3.86). For the males, the E-types had the highest mean ATCAT score (M = 36.56, SD = 6.49). The S-types achieved the lowest mean ATCAT score across the entire sample (M = 30.87, SD = 8.04). and also within the female sample (M = 28.56, SD = 6.77). For the males, the C-type achieved the lowest mean ATCAT score (M = 32.97, SD = 9.07).

The data were analyzed statistically using a 2 X 6 (Gender x Holland Type) ANOVA (Table 4). Cochran's and Bartlett- Box tests indicated that the assumption of homogeneity of variance was not violated. The analysis disclosed a main effect of the Holland Type only ($F(5, 429) = 2.47$, $p < .05$). Thus, the null hypothesis stating that there was no difference in ATC aptitude

Table 3

Means and Standard Deviations of Air Traffic Control Aptitude for Genders and Holland Types

	Holland Types					
Gender	R	I	A	S	E	C
Females						
M	37.75	33.84	32.56	28.56	31.67	31.59
SD	3.86	7.52	9.22	6.77	8.60	8.14
n	4	19	9	25	21	17
Males						
M	34.53	35.74	34.25	33.19	36.56	32.97
SD	6.95	7.43	7.06	8.46	6.49	9.07
n	116	87	12	32	70	29
Total						
M	36.14	34.79	33.40	30.87	34.11	32.28
SD	6.89	7.45	7.88	8.04	7.28	8.67
N	120	106	21	57	91	46

Table 4

Summary ANOVA of Air Traffic Control Aptitude for Gender and Holland Types

Source	df	MS	F	p
Gender	1	170.73	3.09	.079
Holland Types	5	136.18	2.47	.032*
Gender by Holland Types	5	59.63	1.08	.37
Error	429	55.17		

among the Holland Types was rejected. Contrary to speculation in previous reports (Transport Canada, 1991),no difference in ATCAT scores was found between the males ($\underline{M}$ = 34.54) and the females ($\underline{M}$ = 32.66). Further, no gender by type interaction was found. Statistically, the males and females within each type performed alike on the ATCAT. Figure 2 illustrates the means of the 6 types once gender has been collapsed.

Duncan's Multiple Range post hoc analyses of the means revealed that the main effect of the Holland Types resulted from the S-types scoring significantly lower than the R-, I-, and E-types. The other types were not significantly different from one another.

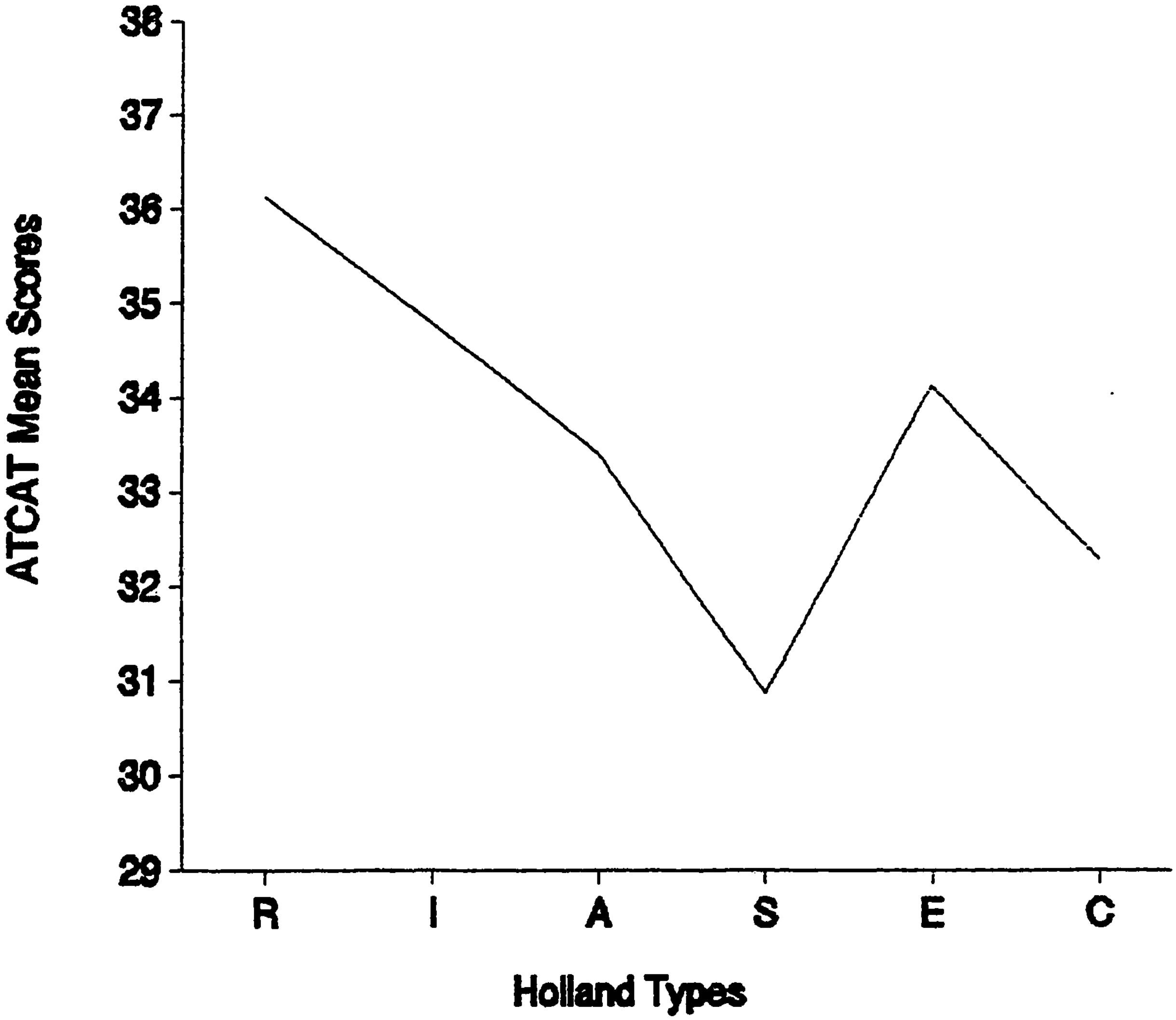

Figure 2. Air traffic controller aptitude test scores of Holland's six types.

Holland Two-Letter Subtypes

Out of the 30 possible combinations, 29 two-letter subtypes were found in the present sample (Table 2). Only the AC's were not represented. Across the entire sample, RI (n = 52) was the most common two-letter subtype. RI was also the most common 2-letter subtype for the males (n = 50), while for females, SI (n = 11) was the most common. Results from 50 participants had to be excluded due to ties between the second and third letters of their profiles. Further, when a two-letter subtype had a frequency of four or less, the data from this subtype were also dropped from the analysis. As a result of the foregoing criteria, 79% (n = 383) of the original sample and 26 of the 29 two-letter subtypes found were retained for analysis (see Table 5). The small number of females in the groups prohibited an analysis of gender differences. Thus, the genders were collapsed and the analysis was conducted across the two-letter subtypes only.

The ATCAT means and standard deviations for each of the two-letter subtypes are presented in Table 5. The AI group had the highest mean ATCAT score ($\underline{M}$ = 39.00, $\underline{SD}$ = 3.16), while the SC group had the lowest mean ATCAT score ($\underline{M}$ = 26.60, $\underline{SD}$ = 8.69). A one-way ANOVA across the two-letter subtypes (26) revealed that

Table 5

Means and Standard Deviations of Air Traffic Control Aptitude for Holland Two-Letter Subtypes

2-Letter	M	SD	n
RI	35.19	6.87	52
RS	32.60	6.77	15
RE	35.84	5.45	25
RC	33.00	7.59	7
RA	36.40	7.02	5
IR	36.08	6.81	38
IE	37.47	5.94	15
IC	32.28	9.36	18
IS	35.58	5.96	12
IA	37.63	4.44	8
AI	39.00	3.16	5
AR	27.67	8.91	6
SE	31.29	9.24	14
SA	34.44	6.62	9
SR	35.43	9.00	7
SI	31.33	5.96	15
SC	26.60	8.69	10
ER	35.24	7.53	21
EI	37.67	7.00	18
EC	32.38	7.98	21
ES	34.39	8.27	13
EA	35.44	7.91	9
CI	33.29	8.60	14
CR	31.89	10.35	9
CI	32.40	6.35	10
CS	33.00	10.80	7

there were significant differences across the groups ($F(25,357) = 1.68$, $p < .05$). A summary of the Anova is presented in Table 6. Cochran's and Bartlett-Box tests indicated that the assumption of homogeneity of variance was not violated. The null hypothesis stating that there is no difference in ATC aptitude among Holland's two-letter subtypes can be rejected.

Table 6

Summary ANOVA of Air Traffic Control Aptitude for Holland Two-Letter Subtypes

Source	df	MS	F	p
2-Letter	25	91.70	1.68	.023*
Error	357	54.56		

Classification of the ATC candidates according to their two-letter subtypes was found to be related to differences in ATCAT performance.

Duncan Multiple Range post hoc analyses further indicate that two sets of differences were responsible for the main effect of the two-letter subtypes. First, the SC's scored significantly lower than the ES, RI, ER, SR, EA, IS, IR, IE, IA, EI, and AI subtypes. Second, the AR's scored significantly lower than the IR, IE, IA, EI, and AI subtypes. No other pairwise comparisons were significant.

Holland Three-Letter Codes

Out of 120 possible combinations, 88 three-letter codes were found in the sample (Table 2). RIE was the most common code across the entire sample (n = 22), and for the males (n = 22). For the females, SIE (n = 7) was the most common three-letter code. Ties between the third and fourth letter of a code required that data from 60 participants be excluded from the analysis. Further, when a three-letter code had a frequency of four or less, the data from this group was omitted. Thus, 39% (n = 190) of the original sample, and 24 of the 88 three-letter codes were included in the analysis. Again, the genders had to be collapsed, and only differences across the codes were considered.

The ATCAT means and standard deviations for each of the three-letter codes are presented in Table 7. The IER group had the highest mean ATCAT score (M = 40.71, SD = 3.50), while the SCE group had the lowest mean ATCAT score (M = 25.80, SD = 7.69). A one-way ANOVA of the three-letter codes (24) revealed that significant differences existed among the groups ($F(23, 163) = 1.67$, $p < .05$). A summary of the ANOVA is presented in Table 8. Cochran's and Bartlett-Box tests indicate that the groups were homogeneous. The null hypothesis stating that there will be no difference in ATC aptitude among the three-letter codes can be rejected. Differences in ATCAT performance did exist among the 24 three-letter codes analyzed.

Duncan Multiple Range post hoc analyses indicated that the: (1) SCE group scored significantly lower than the REI, IRE, IRC, ICE, ERI, EIC, ESR, and IER groups; (2) ICR group scored significantly lower than the IRE, IRC, ICE, ERI, EIC, ESR, and IER groups; (3) CIE group

Table 7

Means and Standard Deviations of Air Traffic Control Aptitude for Holland Three-Letter Codes

3-Letter	M	SD	n
RIE	33.77	7.41	22
RIS	35.13	6.24	8
RIC	33.88	7.88	8
RSI	31.80	10.01	5
RSE	29.80	1.92	5
REI	36.29	5.82	7
REC	34.57	5.80	7
RES	34.17	5.42	6
IRE	36.46	6.77	13
IRC	37.08	6.24	12
IRS	34.14	8.93	7
IER	40.71	3.50	7
ICR	27.14	9.15	7
ICE	37.33	9.05	6
SIE	31.67	7.04	9
SCE	25.80	7.69	5
ERI	37.44	6.88	9
ERC	33.17	9.33	6
EIC	38.00	7.21	6
ECR	35.63	9.13	8
ECS	32.33	7.34	6
ESR	39.00	3.32	7
CIE	28.67	8.89	6
CRE	32.00	11.58	5

Table 8

Summary ANOVA of Air Traffic Control Aptitude For Holland's Three-Letter Codes

Source	df	MS	F	p
3-Letter	23	90.25	1.67	.036*
Error	163	54.15		

scored significantly lower than ESR, and IER groups; (4) RSE group scored significantly lower than the IER group.

CHAPTER V

DISCUSSION

The results of the study supported the three hypotheses: significant differences were found among the types, the two-letter subtypes, and the three-letter codes. In a strict sense, Holland's assumption that his typology encompasses aptitude differences, is thus supported. The results require some important qualification, however, in light of the results of the post hoc analyses. Rather than clearly indicating the types and subtypes that possess ATC aptitude, the results of the Duncan multiple range pairwise comparisons are more easily interpreted in terms of the types and subtypes who do not have ATC aptitude.

Holland Types

Analysis of the Holland types, the primary direction of personality, indicated a significant difference in controller aptitude among the six types. A scrutiny of the post hoc analyses reveals, however, that this difference is accounted for by only one type, the S-type, scoring significantly lower than the R-,I-, and E-types. Thus, while the S-types typically perform below the criterion required for selection by Transport Canada, and relatively poorly compared to the R-, I-, and E-types, the remaining five types (R, I, A, E, C) have a moderate level of controller aptitude and are undifferentiated from one another in controller aptitude. Contrary to what one would expect from the theory, there is no indication of a type (or types) who excel in controller aptitude. Instead, the results suggest only that the S-types are disadvantaged in terms of ATCAT performance.

The poor performance of the S-types is likely to have more of an impact on the female sample since the greatest percentage (24%) of the females classified themselves as S-types. Only 8.4% of the males were S-types, the predominant male type being the R-type (30.4%). Interestingly, despite the preponderance of S-types in the female sample, a significant difference between the performance of the males and females on the ATCAT was not found. The remaining female types appear to have compensated for the poor performance of the S-types. In particular, across both males and females, the R-type females had the highest mean (37.75) with the lowest standard deviation (3.86). Although this group was small, they performed uniformly well. Perhaps recruitment of more R-type females would lead to an increase in the female ATCAT performance.

Holland Two-Letter Subtypes

The significant results of the analysis of the two-letter subtypes require the same type of qualification as the single-letter type results. Post hoc analysis revealed that the significant difference found among the subtypes was primarily due to two of the subtypes, SC and AR, scoring significantly lower than eleven and five of the other subtypes, respectively. The remaining 24 subtypes analyzed were not differentiated in controller aptitude, and similar to the undifferentiated single-letter types, the means of these 24 subtypes tended to be moderate. Surprisingly, the increased personality information provided in the two-letter subtypes did not yield a clearer picture of who excels on the ATCAT.

A survey of the results of the two-letter subtypes are suggestive, however, of certain trends. Of the eleven subtypes the SCs scored significantly lower than, seven had an "I" in their subtypes, while all five of the subtypes the ARs scored significantly lower than had an "I" in their subtype. It may be that the general intelligence and academic aptitude the I-type appears to possess (Elton & Rose, 1970; Kelso et al., 1977; Schneider & Overton, 1983) is a factor in high performance on the ATCAT. More specifically, perhaps the elevated mathematical aptitude exhibited by the I-types has some bearing on ATCAT performance (Holland, 1962; Yonge & Regan, 1975), while the low mathematical aptitude evidenced by the S-types (Holland, 1962) may lead to the poor ATCAT performance of the S-type and Sdominated subtype. Many of the ATCAT items clearly require the ability to rapidly calculate travel times and distances.

Examination of the two-letter subtypes yields another interesting trend. Although the A-types did not score significantly different than the low-scoring S-types in the analysis of the single-letter types, combinations of the A- and I-types in two-letter subtypes (AI or IA) score extremely well on the ATCAT. Among the two-letter subtypes, the AIs and IAs had the first and third highest means, respectively. Alternatively, a combination of the A- and R-types (AR) yields the second lowest mean. Moreover, post hoc analyses reveal that the AR's mean is significantly lower than the AI and the IA subtypes' means. Perhaps the artistic competencies attributed to the A-types enable them to visualize the air traffic dilemmas presented on the simulated radar scope. Combined with the mathematical aptitude of the I-type, this ability may be advantageous for performance on the ATCAT.

Holland Three- Letter Codes

Interpretation and discussion of the three-letter codes must be approached tentatively due to the large attrition resulting from the omission of tied personality profiles and small groups. Notably, the influence of the A-factor cannot be assessed since it is not represented in any of the codes. This is an important absence since combinations of A- and I-types appeared to have promise in terms of ATCAT performance.

While there was a significant difference among the 24 three-letter codes analyzed, post hoc analyses again revealed a fair degree of aptitude overlap among the codes. Only 4 codes performed significant lower than the other codes; the remaining 20 codes were undifferentiated in ATCAT ability. Importantly, the SCE code scored approximately 20% below the criterion required by Transport Canada, and had the lowest cell mean across all three levels of analyses (types, subtypes & codes). The reduction in performance accrued from the S-type (M = 30.87, SD = 8.04), the SC subtype (M = 26.60, SD = 8.69) and the SCE code (M = 25.80, SD = 7.69) suggests an increasing disadvantage with regards to ATCAT ability. Thus, the increasing specificity in Holland's classification gives us a narrower indication of who performs poorly on the ATCAT.

Conversely, the post hoc analysis of the three-letter codes does not clearly indicate specific codes that score high on the ATCAT since 20 of the codes were undifferentiated in controller aptitude. Inspection of the highest scoring three-letter codes does, however, suggest a possible trend. The highest scoring code

(IER) is a combination of the three highest scoring single-letter types. When these types are brought together in one code, the result is the highest cell mean across all three levels of analyses. Moreover, of the eight three-letter codes the SCEs scored significantly lower than, four are combinations of the I-, E-, and R-types. The role of the "I" in these three-letter combinations appears to be important for two reasons. First, it is the primary factor in the highest scoring code (IER). Second, post hoc analysis indicates that replacement of the "I" with an "S" as in the RSE code, leads to a significantly lower ATCAT score than the IER code. The importance of the I-E-R combinations is purely a matter of speculation and should not be overemphasized, however, since post hoc analyses did not reveal a statistically significant difference between these three-letter combinations and codes such as ECS and CRE.

Summary

The results of the present study support the hypotheses that the different types, subtypes and codes are differentiated in controller aptitude. In particular, the S-types, SC subtypes and SCE codes appear to be the least likely candidates for ATC training. The study has, however, failed to bridge the gap between the research regarding ATC aptitude and ATC personality since a personality type, subtype, or code possessing ATC aptitude was not identified. Moreover, from the degree of ATC aptitude overlap, it follows that type-assessment could neither replace ATC aptitude evaluation, nor facilitate the recruitment and selection of persons with ATC aptitude. The vast majority of types, subtypes and codes are undifferentiated in controller aptitude.

The results are also problematic in a purely theoretical sense. If a few of the types, subtypes and codes had scored significantly higher than the remaining types, subtypes and codes this would have provided stronger support for the notion that a narrowing of interests and activities leads to selected competencies and related personality types. Instead, the results revealed a remarkable homogeneity among the types, subtypes and codes in terms of an average level ATC aptitude. The only significant differences arose from the few types, subtypes and codes who had low levels of controller aptitude.

Given that comprehensiveness and independence of categories are desirable characteristics of any typology (Holland, 1985a), the configuration of results arrived at is grounds for scepticism. Holland (1985a) claims that his typology represents the common ways personality and ability coincide in our culture. The inability to isolate types, subtypes or codes who have developed a high level of controller aptitude as a part of their behavioral repertoires may indicate that the typology does not encompass this ability and hence is lacking in comprehensiveness. The results of the present study cannot be used, then, to make an addition to the existing typological formulations, as intended. In terms of the independence of the categories, the theory's hexagonal model leads to the expectation of a certain degree of overlap among the types' characteristics. The extensive overlap in controller aptitude evidenced across all three levels of analysis, however, does not strongly support the notion that the types are even moderately independent regarding their abilities. Although significant differences were found, these points bear consideration.

Recommendations for Future Research

In general, further research is still required to support the key assumption that Holland's typology embodies ability differences. As formulated, the types have many characteristic aptitude differences that require concurrent validation. In particular, investigators need to devise creative, objective ways to operationally define the competencies associated with the Social and Enterprising types in order to validate their typological formulations.

In terms of ATCs, two follow up studies are suggested. The first study is based on the widely held belief among training academy instructors that unsuccessful trainees are not eliminated because they lack academic knowledge, but because they are deficient in applying it (Whitfield & Stammer, 1978). A follow up study could determine whether there is systematic attrition in the Holland types, subtypes and codes who withdraw from or fail controller training. The second study suggested is a comparison of the Holland types, subtypes and codes in different ATC specializations (eg. terminal, tower, or enroute). Studies of other occupations (Wong, 1981) indicate that there are differences in the Holland classifications of persons who gravitate towards different specializations. Perhaps the same is true in air traffic control.

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Appendix A

Description of Civil Service Commission (CSC) Air Traffic Controller Aptitude Screening Test Variables

(from Cobb & Mathews, 1973)

CSC Subtest	Description
Computations	A highly speeded test of arithmetic skill. The problems involve simple addition, subtraction, multiplication, and division. The aptitude factor is referred to as "numerical facility."
Spatial Patterns	A test consisting of two different types of spatial items. In one type, the task is to identify solid figures that can be made from unfolded patterns. In the other type, three different views of an object are presented and the subject must select the correct object from one of four alternatives.

Following Oral Directions	In this test the subject must listen carefully to orally presented directions and information, then discriminate between relevant and irrelevant information in order to proceed toward the proper solution of a series of simple tasks.
Abstract Reasoning and Letter Sequence	In the "Abstract reasoning" portion of the booklet, the task is to indicate which of a series of choices (figures) properly carries out a principle of logical development exhibited by a sequence of figures. In "Letter Sequence" the subject must indicate which of a series of letters properly carries out a principle of logical development exhibited by a sequence of letters.
Air Traffic Problems	A highly speeded test consisting of two parts of 30 items each. In each part, the subject is presented a flight data display for several

aircraft and must determine whether certain changes in altitude may be directed without violating a specified time-separation rule.

Appendix B

Characteristics of Holland Types

Realistic

Activity Preferences: explicit, ordered or systematic manipulation of objects, tools, machines, animals.

Competencies: manual, mechanical, agricultural, electrical, technical. (Deficits: social, educational).

Values: concrete things or tangible personal characteristics (eg., money, power, status).

Traits: asocial, conforming, materialistic, practical, hard-headed, frank, uninsightful, inflexible, persistent, genuine, self-effacing.

Investigative

Activity Preferences: observational, symbolic, systematic and creative investigation of physical, biological and cultural phenomenon.

Competencies: scientific, mathematical. (Deficits: persuasion).

Values: science, understanding and controlling phenomena.

Traits: analytical, curious, introspective, precise, reserved, complex, intellectual, pessimistic, unpopular, unassuming, cautious.

Artistic

Activity Preferences: ambiguous, free, unsystematized activities whereby physical, verbal or human materials are manipulated to create art forms.

Competencies: language, art, music, drama, writing (Deficits: clerical, business).

Values: aesthetic qualities.

Traits: nonconforming, expressive, imaginative, impractical, impulsive, disorderly, introspective, idealistic, original, emotional.

Social

Activity Preferences: the manipulation of others to inform, train, cure, develop, or enlighten.

Competencies: human relations, interpersonal, educational (Deficits: manual and technical).

Values: social and ethical activities and problems.

Traits: cooperative, patient, empathic, friendly, warm, responsible, helpful, sociable, idealistic, persuasive, generous.

Enterprising

Activity Preferences: manipulation of others to attain organizational goals or economic gain.

Competencies: leadership, persuasion, interpersonal (Deficits: scientific).

Values: political and economic achievement.

Traits: adventurous, ambitious, domineering, excitement-seeking, extroverted, self-confident, sociable, optimistic, agreeable, energetic.

Conventional

Activity Preferences: explicit, ordered, systematic manipulation of data to attain organizational or economic goals.

Competencies: clerical, computational, and business system-related. (Deficits: artistic)

Values: business & economic achievement.

Traits: conforming, conscientious, efficient, inflexible, inhibited, methodical, orderly, unimaginative, practical, careful, obedient.

Appendix C

Holland's Secondary Constructs

<u>Consistency:</u> the degree of relatedness among the elements of a personality or environmental profile. For instance R-I subtypes are consistent because R- and I-types have many common characteristics, while C-A subtypes are inconsistent because C- and E-types have many opposite characteristics.

<u>Congruence:</u> the degree of similarity between personality and environmental profiles. For example, maximal congruence occurs when an R-type works in an R-environment, while incongruence exists when an R-type works in an S-environment.

<u>Differentiation:</u> the degree to which a personality or environmental profile resembles a single type. A high-differentiated person would resemble a single type and no other, while a low-differentiated person would resemble each type to the same degree.

<u>Identity:</u> in terms of personality, identity refers to the possession of a clear, well-defined & stable

picture of one's goals, interests, and talents. In terms of environments, identity refers to possession of clear, integrated goals, and rewards that are stable over long time intervals.