THE APTITUDES OF SOFTWARE ENGINEERS

Russell E. Burke

and

Timothy Fitzgerald

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ABSTRACT

This report presents the results of a validation study of 60 computer software engineers employed by the Digital Equipment Corporation in 1992. The software engineers were administered the Johnson O'Connor Research Foundation's standard battery of aptitude and knowledge tests along with a questionnaire assessing their level of satisfaction with a variety of activities related to their jobs.

As a group, the software engineers scored significantly higher than the Foundation's regular adult examinees on fourteen of the seventeen aptitude measures and on a test of Mathematics Vocabulary. When compared with the Foundation's regular examinees who reported satisfaction with their jobs in computer or engineering fields, however, fewer differences were observed. The aptitudes of software engineers seem to be largely the same as those of other computer professionals and engineers: clerical speed, reasoning abilities, spatial ability, numerical abilities, and memory.

The relationships between the aptitude measures and reported satisfaction with job activities were generally in the expected directions but small in magnitude.

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INTRODUCTION

This report presents the results of a validation study of computer software engineers conducted by the Johnson O'Connor Research Foundation/Human Engineering Laboratory (JOCRF) in Boston in January of 1992. The purposes of the study were: (a) to examine the aptitude profile of software engineers, based on a group from a single company who were administered the standard battery of aptitude tests offered by the Foundation, and (b) to investigate the relationships between scores on the aptitude measures and the engineers' level of satisfaction with specific aspects of their jobs.

A *computer program* is a series of instructions that will cause a computer to process data in a particular manner. A *programming system* is "a collection of interacting programs, coordinated in function and disciplined in format, so that the assemblage constitutes an entire facility for large tasks" (Brooks, 1982). Each program within the system must be written in a very precisely prescribed manner to ensure conformity with the other programs within the system. Each must be designed in such a way that it uses only a prescribed amount of the computer's resources (memory, input/output devices, and so on). Each must be tested with all the other system components in all the expected combinations. The entire system must be thoroughly documented (Brooks, 1982).

Software engineering is concerned with the design, development, and implementation of large-scale programming systems on production-model computers and with the management of these complex projects. The group of 60 software engineers tested were selected by their company to create the software that would control a new generation of microprocessors under development.

A previous Foundation study of computer professionals (Statistical Bulletins 1977-3 and 1978-8) reported high scores for the professionals on Analytical Reasoning (ability to arrange ideas in logical sequence), English Vocabulary (knowledge of word meanings), Inductive Reasoning (quickness in seeing relationships among separate facts, ideas, or observations), Number Checking ("Graphoria," or clerical speed), Wiggly Block (a measure of spatial ability), Memory for Design (memory for straight-line patterns), and Number Memory. More than 60% of the computer professionals scored above the general population median on each of these tests, with a significance level at or beyond .05 (Kolmogorov-Smirnov one-sample test).

Of the various occupational groups previously tested by the Foundation, computer professionals would seem to be the most closely related to the software engineers. The present study also investigated similarities between software engineers and several groups of engineers. Because software engineers must thoroughly understand the nature and functioning of the hardware components of the computer systems for which they design software, they might share some aptitudes in common with engineers.

Over the years, the Foundation has conducted a number of studies of engineers. In the earliest studies, engineers scored high on the Wiggly Block test. In addition, significant correlations were found between earnings growth and Personality (word association) test scores, with rapid-earning technical engineers scoring Subjective (indicating a preference for individual work) and rapid-earning engineering managers scoring Objective (indicating a preference for working with others; O'Connor, 1938a, 1938b; Technical Reports 97, 101). In the 1970s, several studies of engineers were conducted, generally finding all types of engineers scoring high on tests of Structural Visualization (Wiggly Block), Analytical Reasoning, Memory for Design, Number Memory, and Finger and Tweezer Dexterity (speed and accuracy in manipulating objects with, respectively, one's fingers and small tools). Unlike the engineers in earlier studies, these engineers tended to score significantly Objective, no matter the type of engineering in which they were engaged (Stowell, 1975; Technical Reports 731, 750, 754, 762). It may be that the rapid growth in engineering and the teamwork necessitated by increasingly complex engineering projects made engineering work more attractive to Objective personalities.

METHOD

Sample

Aptitude scores and occupational data were collected for 60 software engineers from Digital Equipment Corporation (DEC) at the Foundation's Human Engineering Laboratory in Boston in January of 1992. The participants were drawn from a design group of 90 who all worked together at DEC; this group had been selected by DEC from throughout the company to work on an urgent, high-priority project and represented their most-capable people. It is, therefore, a very selective sample. Their scores on some tests may be higher than the scores of more-typical software engineers.

The sample comprised 13 females and 47 males, ranging in age from 26 to 56 years, with a median age of 34.5 years. Experience in software engineering ranged from less than one to 26 years, with a mean of 9.1 years.

Thirty-three had either bachelor's or master's degrees in computer science (one was reported as a degree in electrical engineering with a concentration in computer science); another 6 had degrees in computer engineering. Two had studied computer science after receiving unrelated bachelor's degrees, and 6 had studied computer science but received no degree. Four had degrees in engineering, while the remaining 9 members of the group had no educational background in computer work but were self-taught or were trained on the job. Of these, 6 had degrees and 3 had no college degree.

Some of the analyses performed for this study used the Foundation's population of examinees who pay a fee for the testing service, usually for the purposes of educational or career guidance. The Foundation has testing offices in 11 cities: Atlanta, Boston, Chicago, Dallas/Fort Worth, Denver, Houston, Los Angeles, New York, San Francisco, Seattle, and Washington, D.C. The JOCRF examinee population is a relatively homogeneous group with regard to education and socioeconomic status. In the main they are white and middle- to upper-middle class. The great majority of examinees are college-bound or college-educated: on average, adult examinees have over 16 years of schooling (16.1 for females, 16.6 for males), while their fathers average 16.1 and mothers 14.8. Almost half the Foundation's testing population is over age 25, and of these, about three-quarters have been in their jobs for at least one year (mean 4.4 years) (Statistical Bulletin 1994-4). Although it might be assumed that adults seek aptitude testing due to dissatisfaction with their career choices or direction, over 40 percent report satisfaction with their jobs, while only 25 percent report dissatisfaction. However, these satisfaction levels are based on self-report and may not be as high as indicated. Foundation examinees were used in this study solely to provide comparably educated samples against whom the scores of the software engineers could be compared.

Measures

The software engineers were administered the standard battery of aptitude tests offered by the JOCRF at the time they were tested, with the exception of Analytical Reasoning and Observation. For these two tests, versions under development were administered: Analytical Reasoning, Wks. 244 G*, with minor changes, is now the standard version of the test (see Technical Report 1992-1, p. 28), while Observation, Wks. 744 B*, is still under development (Ransom, 1991). A description of the aptitudes measured is contained in Table 1. In addition, the software engineers took two knowledge tests, English Vocabulary and Mathematics Vocabulary.

Additional data were obtained from the standard Information Sheet in addition to a questionnaire designed specifically for the software engineers. Since the engineers were engaged in a complex project that involved many different tasks, the questionnaire was designed to determine the particular tasks that a given engineer performed and the degree to which he or she enjoyed them. These tasks were:

1. CODING—writing programs or testing procedures.
2. DESIGNING—writing design specifications, functional specifications, or architectural specifications.
3. PROBLEM ANALYSIS AND DEBUGGING—analyzing a problem, debugging a program, trouble-shooting a specific problem.
4. PROJECT LEADING—technical and delivery responsibility for a project. Responsible for planning, scheduling, tracking milestones, and making corrections.

Table 1

Aptitudes Measured by the Standard Foundation Battery

Name	Reliability[a]	Trait measured
Graphoria, Wks. 703 AB	.96	Clerical speed and accuracy; measured by Number Checking, which involves quickly comparing pairs of numbers to see whether they are the same or different.
Ideaphoria, Wks. 161 AM/CM	.97	Rate of flow of ideas (ideational fluency).
Foresight, Wks. 307 AO/CO[b]	.97	–
Inductive Reasoning, Wks. 164 MB	.84	Quickness in seeing relationships among separate facts, ideas, or observations.
Analytical Reasoning, Wks. 244 G*[c]	.83	Ability to arrange ideas into a logical sequence.
Numerical Reasoning, Wks. 707 BB	.87	Ability to reason (solve problems) with numbers. Measured by the Number Series test.
Numerical Facility, Wks. 436 IA	.82	Ability to perform arithmetic operations quickly. Measured by the Number Facility test.
Structural Visualization, Wks. 34555/6 AH + 622 FC	.86	Ability to visualize three-dimensional forms. Measured by Wiggly Block (reconstructing a three-dimensional block) and Paper Folding (rotating two-dimensional surfaces through three-dimensional space).
Subjective vs. Objective Personality, Wks. 35 AQ	.89	Distinction between individuals whose instinctive mental associations resemble those of a large percentage of other persons, and individuals whose associations are unlike those of the majority. The former are said to have objective personalities; the latter, subjective personalities. (Describes how well-suited a person is for working in a group [Objective] versus working on one's own as an individual [Subjective].) Measured by the Word Association test.

Table 1 (*continued*)

Name	Reliability	Trait measured
Tonal Memory, Wks. 498 BQ	.92	Ability to remember sequences of tones.
Pitch Discrimination, Wks. 315 FE	.80	Ability to perceive fine differences in pitch.
Rhythm Memory, Wks. 366 BD	.73	Ability to remember complex rhythmic patterns.
Memory for Design, Wks. 294 UO	.80	Memory for straight-line patterns.
Silograms, Wks. 376 AJ	.92	Associative memory for verbal material.
Number Memory, Wks. 165 AO	.82	Memory for numbers.
Observation, Wks. 744 B*[d]	.72	The ability to retain a mental image of various objects in the mind and quickly perceive any changes in the nature or position of an object.
Finger Dexterity, Wks. 16 ED	.86	Speed and accuracy in manipulating small objects with one's fingers.
Tweezer Dexterity, Wks. 18 JO	.93	Speed and accuracy in handling small objects with tweezers.

Note. The software engineers also took English Vocabulary, Wks. 690 AC/BC/CC/DC/EC/FC, with a reliability of .96, and Mathematics Vocabulary, Wks. 694 AB, for which no reliability coefficient is available. These tests measure knowledge of the meanings of nontechnical English words and mathematical terms, respectively.

[a]Source for reliability coefficients: Statistical Bulletin 1988-2.
[b]Formerly thought to measure an "ability to keep one's mind on a long-range goal." Measured by showing the examinee a simple line drawing and asking him to "write down as many things as you can that the drawing makes you think of, looks like, reminds you of, or suggests to you." Removed from the standard battery pending further validation.
[c]The software engineers were given an experimental version of the Analytical Reasoning test, Wks. 244 G*, which differed from Wks. 244 HA on only one of the thirteen items. Norms for Wks. 244 HA were used in scoring, and the reliability coefficient for Wks. HA (Technical Report 1992-1) is given here.
[d]The software engineers took an experimental version of the Observation test, Wks. 744 B*. The reliability coefficient reported here is based on data from 384 unselected cases from the Foundation's New York office (Ransom, 1991).

5. TECHNICAL CONSULTING—providing technical advice to people within the group and company.
6. PERFORMANCE MODELING—predicting performance of a system and devising ways to test and measure performance.
7. TEST DEVELOPMENT—defining tests needed as proof of correctness. Also includes writing and execution of test programs and analysis of results.
8. TECHNICAL LEADERSHIP—working individually and through others to set technical product direction and strategy. Reviewing project plans and design specifications to assure that implementation is consistent with direction.
9. MENTORING/TRAINING—passing on technical expertise and product knowledge to others and/or to customers. Can involve writing of technical articles for publication, presentations in public forums.
10. DOCUMENTATION REVIEW AND INPUT—providing documentation input and reviewing product manuals and technical papers.

Participants were asked to indicate the approximate percentage of their time spent in each of these activities, and to rate their degree of satisfaction with each of the tasks they performed, using a four-point scale (1 = enjoy very much, 2 = enjoy moderately, 3 = dislike moderately, 4 = dislike very much). Our purpose was to examine the relationship between aptitude test scores and satisfaction with these job tasks.

Analyses

The aptitude and vocabulary tests were scored using the percentile norms in use by the Foundation at the time of the study. The use of age-based norms corrected for any differences related to age. Norms for Analytical Reasoning were based on 1,953 Foundation examinees who took Form HA in 1993. Form HA and Form G* (the version the software engineers were given) were identical with the exception of one item. Norms for Observation 744 B* were based on the scores of 384 persons tested in the Foundation's New York office in 1991 and 1992.

For this study, the percentile scores were converted to *z*-scores, calculated with reference to the Foundation's general population of examinees. This transformation creates a score that represents the deviation of a given score from the mean, expressed in standard deviation units. A *z*-score of 0 represents the 50th percentile, and so negative *z*-scores show how far below the mean a given score is, while positive *z*-scores show how far above the mean a score is. The use of such an interval scale of measurement allows for parametric methods of analysis. All analyses performed for this project used *z*-scores rather than percentile scores.

For the Personality test, which is normally reported in raw scores, raw scores were converted to percentiles, and the percentiles were then converted to *z*-scores. The division between Objective and Subjective personalities occurs at the 25th percentile, or a *z*-score of -0.67.

To evaluate whether the software engineers scored significantly differently from the general Foundation testing population, a one-sample Kolmogorov-Smirnov test was performed on the scores for each test, comparing the software engineers' mean to a normal distribution with a mean of 0 and standard deviation of 1. (One may recall that the software engineers were assigned z-scores relative to the general Foundation mean and standard deviation. Hence the Kolmogorov-Smirnov test represented a comparison between the software engineers and the general Foundation testing population.) A significance level of .05 was set for all statistical tests reported in this study. The size of the effect associated with each test was calculated as the difference between the engineers' sample and the general population mean divided by the general population standard deviation. Since these analyses used *z*-scores calculated with reference to the Foundation's testing population, the population mean is 0 and standard deviation is 1, and thus the effect size is the same as the sample mean. An obtained effect size of .10 *SD* means the software engineers scored on the average at approximately the 54th percentile of the Foundation population; an effect size of .25 *SD*, at approximately the 60th percentile.

The Foundation has established several criteria for determining which aptitudes to include in an occupational profile (Statistical Bulletin 1986-9; Technical Report 1986-2). These include:

1. The difference between the sample mean and the general population mean must be significant at the .05 level.

2. This difference between the means must also be practically significant, i.e., the effect size must be greater than three-tenths of a standard deviation.

3. For any sample mean that is significantly higher than the general population mean, the lower bound of the 90% confidence interval (CI) for the mean must be above the general population mean by more than .3 times the standard error of the sample mean (SE), and for any sample mean that is significantly lower than the general population mean, the upper bound of the 90% confidence interval for the mean must be below the general population mean by more than .3 times the standard error of the sample mean.

4. At least 60% of the sample should score above the 50th percentile of the general population.

5. The aptitude must be relevant to the functional requirements of the occupation.

6. The result obtained in the study must be confirmed by other research.

All of these requirements were addressed in the analyses of the software engineers' scores.

In a further set of analyses, the software engineers' scores were compared with several subpopulations of the Foundation's regular examinees. These included those examinees whose ages, educational levels, and specific educational majors or occupations were similar to those of the software engineers. Samples were selected from the Foundation's computerized database of examinees tested between 1989 and 1994. Only examinees between the ages of 26 and 56 (the software engineers' range) with 13 or more years of education were selected. Groups were further defined by reported college major (engineering or computer science fields), by reported occupational field (engineering or computer-related occupations), and by reported level of satisfaction with these occupational fields. A thorough description of these comparison groups is given in Appendix B. Because there are sex differences on some of the aptitude measures (notably Structural Visualization, Graphoria, and Ideaphoria), a comparison was made between the scores of the males in the sample and male regular examinees of the same age and education levels. For all these comparisons, the Mann-Whitney *U* test was used to evaluate the statistical significance of differences between scores obtained by the software engineers and the regular Foundation examinees. (See the "Sample" section for information about JOCRF examinees.)

Preliminary analysis of the software engineers' questionnaire responses revealed that they were, in general, very satisfied with all or nearly all of their job tasks. Very few expressed even moderate dislike for the tasks. Because of this high level of satisfaction, responses to the satisfaction questionnaire were analyzed using *t*-tests to evaluate differences in means between those who enjoyed a given task very much and those who enjoyed it less (i.e., enjoy moderately or dislike at all).

RESULTS AND DISCUSSION

Aptitude and Knowledge Tests

Table 2 presents the means, standard deviations, and *p*-values of the software engineers' *z*-scores, their mean percentile ranks on the Foundation's aptitude tests, and the percentage of the sample scoring above the general population's 50th percentile. As noted above, because the Foundation general population mean is 0 and standard deviation is 1, the effect size is the same as the sample mean. Appendix A presents the actual distributions of the software engineers' scores on the tests.

Compared to the general population of Foundation examinees, the software engineers scored significantly higher on fourteen of the eighteen aptitude tests (Structural Visualization is not itself a test, but a combination of the scores on the Paper Folding and Wiggly Block tests). The fourteen tests included the six aptitude measures in which computer professionals had obtained high scores in the previous Foundation study (Statistical Bulletin 1978-8): Graphoria, Wiggly Block, Analytical Reasoning, Inductive Reasoning, Memory for Design, and Number Memory. In addition, the software engineers scored significantly higher than the general

Table 2

Mean Test Scores of Software Engineers

Test	*Z*-score mean/ES[a]	*SD*	*p*	Percentile mean	Percent >50%ile
Graphoria	.59	.98	<.001	65.85	76.7
Ideaphoria	.36	1.09	.001	60.28	61.7
Foresight	-.02	.78	>.05	50.08	51.7
Inductive Reasoning	.38	.97	<.001	62.15	71.7
Analytical Reasoning	.59	1.09	<.001	66.42	71.7
Number Series	.71	.97	<.001	69.68	80.0
Number Facility	.60	.95	<.001	67.60	71.7
Structural Visualization	.77	.91	<.001	72.17	78.3
Wiggly Block	.61	.98	<.001	67.32	68.3
Paper Folding	.83	.94	<.001	72.67	76.7
Tonal Memory	.21	1.02	>.05	54.97	53.3
Pitch Discrimination	.18	.98	>.05	55.08	53.3
Rhythm Memory	.40	.94	<.001	61.20	63.3
Memory for Design	.85	.92	<.001	74.65	85.0
Silograms	.42	.76	<.001	63.23	66.7
Number Memory	.67	.88	<.001	68.92	73.3
Observation	.14	.87	>.05	53.55	51.7
Finger Dexterity	-.28	.82	.007	40.90	31.7
Tweezer Dexterity	.52	.86	<.001	65.55	66.7
Word Association	.54	.81	<.001	66.62	75.0
English Vocabulary	.23	.87	>.05	56.75	60.0
Math. Vocabulary	1.30	.59	<.001	86.95	96.6

Note. ES = effect size, *SD* = standard deviation, *p* = probability level. Percent > "50%ile" = percentage of examinees that scored above the 50th percentile. High scores on Word Association, or Personality, indicate Objectivity, while low scores indicate Subjectivity. A *z*-score of -.67 divides Objective and Subjective personalities.

[a]Effect size was calculated using a population mean of 0 and a population standard deviation of 1, thus making effect size the same as the sample mean.

population in Ideaphoria, Number Series, Number Facility, Paper Folding, Tweezer Dexterity, Silograms, Rhythm Memory, and Word Association (i.e., significantly more Objective). They scored significantly lower than Foundation examinees in Finger Dexterity. On the two vocabulary measures, the software engineers scored significantly higher than the general population on Mathematics Vocabulary but not on English Vocabulary, although 60% of them did score above the 50th percentile for English Vocabulary.

The results of the comparisons of the software engineers with the various subpopulations of regular Foundation examinees are shown in Appendix C. The findings with regard to the overall Foundation population are replicated when the software engineers are compared with regular examinees within the same age and education range (age 26-56, education 13 years or more). The only exceptions are that the software engineers are not significantly lower in Finger Dexterity than the matched group and are significantly higher in English Vocabulary.

The results of the comparison of male software engineers and male regular examinees in the same age and education range are shown in Appendix D. The male software engineers scored significantly higher than the male regular examinees on the same fourteen aptitude tests; because males constituted three-quarters of the sample of software engineers, the male means are nearly identical to the means for the software engineers as a whole. The only significant difference between women and men among the software engineers was on the Finger Dexterity test, in which the difference almost precisely matched the sex difference in the general population.

With a few exceptions, the differences between the software engineers and the general Foundation population also held between the software engineers and the regular Foundation examinees who majored in engineering and computer science; however, there were fewer differences between the software engineers and regular examinees who worked in engineering and computer fields and also reported being satisfied with their jobs. These will be discussed below.

For all the tests named above except English Vocabulary, the effect sizes were at least three-tenths of a standard deviation, and all met the standard regarding the bounds of the 90% confidence interval (that is, for Finger Dexterity, the upper bound of the CI was more than .3 SEs below the mean; for all the other tests, the lower bound of the CI was more than .3 SEs above the mean). For each of these tests, more than 60% of the sample scored above (or, in the case of Finger Dexterity, below) the general Foundation population's 50th percentile.

Structural Visualization. The software engineers scored much higher in Structural Visualization than general Foundation examinees, with over half the group scoring above the 75th percentile and only 18.3% scoring below the 50th percentile. On the subtests, 56.7% scored in the top quarter on the Paper Folding test, and 48.3% were in the top quarter on the Wiggly Block test. The software engineers score significantly higher on the Structural Visualization tests than regular examinees who majored in engineering or computer science.

In comparison, the Foundation's 1978 study of computer professionals reported a median Wiggly Block score of the 65th percentile for males ($p < .01$) and the 63.5th percentile for females ($p < .001$).

Memory for Design. The software engineers also scored in the expected direction on Memory for Design, with a mean at about the 75th percentile. 85% of the group scored above the 50th percentile, and over 60% scored in the top quartile. The group scored significantly higher than those who majored in engineering or computer science, but the difference disappears when the comparison is with persons working in those fields and satisfied with their jobs.

The 1978 study also reported high scores on Memory for Design for the computer professionals, with a median percentile of 73.5 ($p < .05$).

Graphoria. Slightly more than three-quarters of the software engineers scored above the 50th percentile. The mean is significantly higher than for engineering majors, but the difference does not hold when compared with those reporting satisfaction in engineering nor with any group of computer science majors or computer professionals. The 1978 study reported 69% of the computer professionals scoring above the general population median on the Number Checking test, with a sample median at the 68th percentile ($p < .01$).

Inductive Reasoning. As with the 1978 sample of computer professionals, the software engineers scored significantly higher than the general population on the Inductive Reasoning test, with virtually the same percentage (70% in the earlier study, 72% in the present sample) scoring above the 50th percentile. The sample scored significantly higher than engineering and computer science majors.

Analytical Reasoning. Almost half (29) of the software engineers scored above the 75th percentile on this test; one-third scored at or above the 90th percentile. In this ability, the software engineers differed very little from those who majored in engineering, those who worked in engineering, and those who reported satisfaction with their work in a computer science field. This is in line with previous Foundation studies, which have found both computer professionals and engineers obtaining high scores on this test. The 1978 study of computer professionals reported a median Analytical Reasoning score at the 80th percentile, with 73% of the sample scoring above the general population median ($p < .01$). Studies of engineers during the 1970s reported Analytical Reasoning medians generally at about the 80th percentile (Stowell, 1975; Technical Reports 731, 750, 754, 762).

Ideaphoria. The mean score of the software engineers on the Ideaphoria test was at the 60th percentile, with 41.7% scoring in the top quartile. Not only is this mean significantly higher than the general population mean, but it is significantly higher than most of the groups of engineering and computer science majors and professionals. The only exceptions were engineering majors working in the computer field and computer professionals who reported satisfaction with their work. The 1978 study of computer professionals reported scores at, or slightly above, the general population median, with no differences achieving significance. In Brown's 1972 study (Technical Report 762), about 60% of the engineers scored above the general population median (no significance test was reported).

Vocabulary. The software engineers' mean on the Foundation's test of general English Vocabulary knowledge was near the 57th percentile, falling short of statistical significance on the one-sample test. However, 60% of the sample scored above the general population mean, and their scores were significantly higher than nearly all the matched age and education subgroups with whom they were compared (the exceptions being engineers working in the computer profession and computer professionals reporting satisfaction with their work). The 1978 study of computer professionals reported a similar median (61st percentile, the current sample median being the 60th percentile), but a larger percentage (72% versus 60% of the present sample) scoring above the general population average. Previous studies of engineers tended to find scores slightly below average.

The software engineers scored exceptionally high on a test of Mathematics Vocabulary knowledge: half scored at the 95th or 99th percentile, with the group mean at the 87th percentile.
Only two examinees scored below the general population mean. The Foundation normally administers the Mathematics Vocabulary test only to examinees under age 25, so the comparison group on this test is primarily high school and college students, who would be expected to have taken mathematics courses more recently than most of the software engineers. The software engineers, on the other hand, probably use their mathematical knowledge daily. None of the Foundation's previous studies of engineers and computer professionals reported Mathematics Vocabulary scores, and almost none of the more recent examinees matched by age and education had taken the test, so it is impossible to say how the software engineers' scores would compare with scores of other engineers or computer professionals. However, a number of studies have found strong correlations between mathematics ability and performance on tests of "computer aptitude" (e.g., Chung, 1988; Coates & Stephens, 1990; Dambrot, Watkins-Malek, Silling, Marshall, & Garver, 1985; Hearne & Lasley, 1985; Hearne, Poplin, & Lasley, 1987) and performance in computer science or programming courses (e.g., Dambrot, Silling, & Zook, 1988; Guinan & Stephens, 1988; Koubek, LeBold, & Salvendy, 1985; Webb, 1985).

Number Memory. The software engineers scored significantly higher than Foundation examinees in Number Memory, with 45% scoring in the top quartile. They were significantly higher than other engineering and computer science majors but not higher than regular examinees who reported being satisfied with their jobs in a computer science field. This is similar to the finding of the 1978 study, which reported a median Number Memory score at the 86th percentile.
Studies of engineers have been mixed, with some groups averaging high scores and others not.

Silograms. The present sample scored significantly higher than the general population in

Silograms, a test requiring one to memorize English meanings for a number of nonsense words. Twenty-nine software engineers (nearly half) scored at or above the 70th percentile. The ability to learn new words easily may be helpful for learning computer languages and/or technical terms. Previous studies of computer professionals and engineers have generally not found significantly high scores on this test.

Numerical abilities. The software engineers scored significantly higher than the general population of Foundation examinees in both Number Series and Number Facility. The former is thought to measure an aptitude for identifying and reasoning with numerical relationships, while the latter is considered to assess an aptitude for performing arithmetic operations quickly. The sample scored very high on both tests but not significantly higher than other computer science and engineering majors or professionals (except on Number Facility, on which they scored higher than the computer science majors). It seems unlikely that people lacking numerical abilities would be drawn to these fields, which tend to require a good deal of mathematical training.

Earlier Foundation studies have not included these tests, which were added to the standard battery comparatively recently. Programmers and engineers are typically found to score high on tests of numerical ability, such as the Numerical subtest of the General Aptitude Test Battery. See also the earlier discussion of Mathematics Vocabulary, where it is noted that several studies have found strong relationships between mathematics ability and performance on “computer aptitude” tests and in computer courses.

Dexterity. The software engineers scored significantly higher than Foundation examinees in Tweezer Dexterity, speed and accuracy in handling small objects with tweezers, thought to indicate an aptitude for detail work with small tools. The present sample did not score significantly higher than other examinees who were working in the engineering field or engineering majors working in the computer field but did score significantly higher than all the other comparison groups. The Foundation’s studies have consistently found high Tweezer Dexterity scores among engineers of all kinds; the scores of computer professionals in the 1978 study were not significantly higher than the general population.

The software engineers in this study scored significantly lower in Finger Dexterity, which measures an aptitude for manipulating small objects with the fingers, than the general Foundation population, with a mean score at the 41st percentile. This does not accord with the 1978 study, which did not find computer professionals to be significantly different from the general Foundation population, nor with most of the Foundation’s studies of engineers, which tended to find them scoring high. In the present sample, women averaged significantly higher scores than men; the difference, about .7 *SD*, is precisely the same as that found in the Foundation’s general testing population between men and women (see the *Finger Dexterity Test Worksample 16 Manual*). Male software engineers did not score significantly differently than male regular examinees, nor did female software engineers score differently than female examinees: in other words, the low average score of the software engineers is probably explained by the high percentage of males in the group.

Auditory aptitudes. The software engineers scored significantly higher than the general population on Rhythm Memory. This held true against examinees within the same age and education range but not against those with engineering or computer science majors or occupations. A group of electronics engineers tested in the late 1950s and early 1960s (Stowell, 1975) obtained high Rhythm Memory scores; no other engineering studies reported Rhythm Memory scores at all. The 1978 study of computer professionals did not find particularly high Rhythm Memory scores.

Brown's 1972 study (Technical Report 762) reported that mechanical and electrical engineers scored high in Pitch Discrimination, and the 1978 study of computer professionals found high scores on one version but low scores on another version of the Pitch Discrimination test. The electronics engineers in Stowell's study had a mean percentile of 61.6 on the Tonal Memory test, but this was not statistically significant. The software engineers in the current study did not score significantly higher on these two tests than any other group with whom they were compared.

Personality. The software engineers averaged significantly more Objective on the Word Association test than all the other groups with whom they were compared, with the sole exception of engineers reporting satisfaction with their work. On this test, persons scoring in the bottom quarter of the general testing population are considered Subjective, and the other three-quarters are Objective. Among the software engineers, 56 of the 60 (93.3%) scored in the Objective range, with three-quarters scoring above the general population mean.

The computer professionals in the 1978 study scored slightly lower than the general population median. All the groups of engineers in the studies from the 1970s scored significantly higher than the general population. The Foundation believes that the ability to work comfortably as part of a team, as in the project for which the software engineers were brought together, is a characteristic of Objective Personalities. It is possible that these software engineers were selected because they work well in teams.

Validation Questionnaire

In general, the software engineers were highly satisfied with and enjoyed their work. Other factors apart from aptitudes may play a role in this high level of satisfaction. Within the company for which they worked, these software engineers had been specifically selected by management to work on an extremely urgent, high-priority project. Thus, they likely represented the most talented and highly motivated of the company's employees. Furthermore, the company itself had been noted for both innovative management strategies and high salaries.

The software engineers reported that they enjoyed most of their job tasks. Fifty-eight of the sixty reported enjoying some aspect of their work very much; on average they reported spending 63.5% of their time in tasks they enjoyed a great deal. The 46 who reported enjoying at least one task to a moderate degree averaged slightly more than 40% of their time in those tasks. Only five reported strongly disliking some aspect of their work. One of those examinees reported spending 80% of his time in a task he strongly disliked (interestingly, it was the task found most enjoyable by the majority of the software engineers, problem analysis/debugging). Only sixteen software engineers reported a moderate dislike for some aspect of their work. If the one truly disgruntled software engineer is not included, the other 18 who reported disliking one or more aspects of their jobs to some degree averaged only about 15% of their time spent in such tasks. On the whole, the group averaged 93.8% of their time in tasks they reported enjoying at least moderately.

Due to this very high overall level of satisfaction, no meaningful comparisons could be made among all four levels of satisfaction with job tasks (enjoy very much, enjoy moderately, dislike moderately, dislike very much). For these analyses, the aptitude scores of those who reported enjoying "very much" the job tasks they performed were compared with the scores of those who performed a specific task but did not report that they enjoyed the task "very much." In other words, software engineers who performed a specific job task were divided into two groups:
those reporting they enjoyed the task "very much" and all others. *T*-tests were used to compare the means of the two groups. The results are shown in Table 3 for 8 of the 10 tasks. For the remaining two tasks, the groups were not large enough to permit meaningful comparisons. A discussion of the results obtained for the job tasks follows.

Coding. Coding is the actual writing of computer programs, subprograms, or test routines. This task was performed by 46 of the 60 software engineers; 31 enjoyed coding very much and 15 felt otherwise (14 "enjoy moderately," 1 "dislike moderately"). Coding was one of the tasks occupying the greatest percentage of the software engineers' time. Of the 46 who spent time on coding tasks, the average was 27.3% of working time. If each member of the group worked an eight-hour day, coding was one of only two tasks occupying over 100 man-hours each day. The overall satisfaction rating was 1.35 (a score of 1 represented "enjoy very much," a score of 4 "dislike very much").

No significant differences were found between groups, but there were a few observed differences in group means that were in directions that might be expected. Those who enjoyed coding very much had mean z-scores more than .30 standard-deviation units higher than those who derived less enjoyment from the activity on Analytical Reasoning, Memory for Design, and Number Memory and scored more than .40 standard deviations lower on Ideaphoria (which might be thought to distract one from tasks requiring focused attention to detail).

Design. Design involves writing the specifications other programmers will need to follow to write specific parts of a program. The questionnaire defined three types of design: writing design specifications (specifying what the program needs to do), functional specifications (showing how the problem will be solved), and architectural specifications (describing relationships and interfaces between programs). However, only five of the software engineers reported spending any time in writing functional specifications, and only four in writing architectural specifications, so all responses were combined into a single category Only two

Table 3

Standard Score Means for Levels of Satisfaction with Job Tasks

	Job task					
	Coding		Design		Debugging	
	Sat. level		Sat. level		Sat. level	
	1	2-3	1	2-3	1	2-4
n	31	15	17	11	39	15
Graphoria	.59	.59	.65	.60	.56	.73
Ideaphoria	.19	.58	.68	.12	.09	.83
Foresight	-.17	.18	.02	-.40	-.14	.07
Inductive Reasoning	.22	.43	.32	-.01	.37	.64
Analytical Reasoning	.67	.33	.84	.07	.56	.56
Number Series	.78	.50	.89	.49	.67	.50
Number Facility	.53	.49	.29	.90	.53	.76
Structural Visualization	.83	.68	1.08	.53	.77	.43
Wiggly Block	.65	.46	.90	.61	.62	.59
Paper Folding	.93	.71	1.11	.46	.86	.59
Tonal Memory	.19	.54	.20	-.09	.08	.35
Pitch Discrimination	.20	.24	-.04	.59	.08	.24
Rhythm Memory	.52	.46	.73	.24	.34	.25
Memory for Design	.96	.54	1.02	.53	.94	.38
Silograms	.40	.34	.65	.01*	.42	.23
Number Memory	.76	.35	1.05	.66	.88	.17*
Observation	.18	-.00	.24	-.06	.25	-.06
Finger Dexterity	-.32	-.32	-.59	-.26	-.34	-.06
Tweezer Dexterity	.41	.59	.66	.60	.47	.73
Word Association	.63	.21	.67	.73	.63	.24
English Vocabulary	.15	-.08	.75	-.42*	.25	-.05
Mathematics Vocabulary	1.23	1.29	1.53	.94*	1.24	1.26

Table 3 (*continued*)

	Job task					
	Project leading		Technical consulting		Technical leadership	
	Sat. level		Sat. level		Sat. level	
	1	2-4	1	2-4	1	2
n	11	23	26	13	12	6
Graphoria	.91	.69	.62	.35	.43	.65
Ideaphoria	.59	.43	.65	.11	.72	.66
Foresight	.07	.26	.17	-.53*	.20	.15
Inductive Reasoning	.79	.29	.35	.13	.28	.54
Analytical Reasoning	.75	.76	.50	.68	.40	1.06
Number Series	.75	.82	.75	.58	.80	.94
Number Facility	.83	.63	.65	.93	.68	.18
Structural Visualization	.59	.91	.68	.72	.84	1.24
Wiggly Block	.72	.71	.40	.62	.74	.95
Paper Folding	.45	1.00	.94	.82	.82	1.49
Tonal Memory	.11	.34	.39	-.10	.15	.25
Pitch Discrimination	.04	.25	.14	.25	.72	.02
Rhythm Memory	-.03	.42	.57	.28	.26	.21
Memory for Design	1.11	.75	.88	.84	.63	.80
Silograms	.27	.73	.32	.52	.37	.19
Number Memory	.64	.78	.67	.50	.32	.80
Observation	.27	.02	.14	-.19	.41	.29
Finger Dexterity	.29	-.40*	-.43	.14*	-.18	-.54
Tweezer Dexterity	.43	.54	.42	.52	.92	.69
Word Association	.55	.56	.54	.59	.81	.03*
English Vocabulary	.39	.47	.37	.14	.48	-.23
Mathematics Vocabulary	1.19	1.46	1.26	1.17	1.29	1.24

Table 3 (*continued*)

	Job task			
	Mentoring		Document review	
	Sat. level		Sat. level	
	1	2-4	1-2	3
n	17	11	12	9
Graphoria	.43	.49	.77	.31
Ideaphoria	.20	.32	.33	-.06
Foresight	-.18	.04	.13	-.13
Inductive Reasoning	.34	.33	.21	.46
Analytical Reasoning	.01	1.09*	.52	.53
Number Series	.62	.84	1.11	.45
Number Facility	.50	.38	.89	.40
Structural Visualization	.48	1.10	.48	.54
Wiggly Block	.43	.83	.38	.15
Paper Folding	.54	1.23	.55	1.09
Tonal Memory	-.12	.26	-.04	.24
Pitch Discrimination	.05	.06	.22	.00
Rhythm Memory	-.01	.63	.54	.47
Memory for Design	.80	1.11	.60	.72
Silograms	.38	.77	.52	-.07
Number Memory	.34	.95	.92	.60
Observation	-.05	.05	-.19	.20
Finger Dexterity	-.05	-.54	-.40	-.41
Tweezer Dexterity	.35	.55	.37	.28
Word Association	.50	.58	.60	.78
English Vocabulary	.22	.56	.59	-.09*
Mathematics Vocabulary	1.08	1.70*	1.37	1.36

Note. Sat. level = satisfaction level, *n* = number of examinees. Satisfaction codes: 1 = Enjoy very much, 2 = Enjoy moderately, 3 = Dislike moderately, 4 = Dislike very much. Two tasks on the questionnaire, performance modeling and test development, were not included here because the groups performing the tasks were too small to permit sound comparisons.

* Difference in means significant at .05 level.

persons responded for more than one category of specifications, and both reported enjoying all "very much". Twenty-eight of the software engineers worked at this task, and 17 enjoyed it very much; the average satisfaction rating was 1.43. Those who reported performing this task averaged 17.8% of working time on it. The software engineers who enjoyed Design very much scored significantly higher in English Vocabulary, Mathematics Vocabulary, and Silograms than those who enjoyed Design to a lesser extent.

Problem analysis and debugging. Problem analysis and debugging involves solving specific problems within a program as they arise. This was the task performed by the greatest number of software engineers (54) and enjoyed most (39 reporting that they enjoyed it very much, with an average satisfaction rating of 1.31). They spent an average of 31.7% of their time in this task; as with coding (see above), if an eight-hour day is assumed, debugging occupied more than 100 man-hours per day in this group.

Those who enjoyed this task very much averaged significantly higher scores on Number Memory than those who enjoyed it less, and significantly lower scores on Ideaphoria. They also scored higher on Memory for Design, though this difference was not significant. (In this instance, the one software engineer, mentioned previously, who reported spending 80% of his time on debugging and disliking it very much was the only member of the group who expressed dislike for the task. When the analysis is confined to the differences between those who enjoyed the task very much and those who enjoyed it moderately, the same results are obtained except that the difference in Memory for Design scores is significant at the .05 level.)

Project leading. Project leaders are responsible for organizing a group of software engineers to complete a specific project. Thirty-four software engineers cited project leading as one of their job tasks: 11 enjoyed it very much, 17 moderately, and 6 did not enjoy the task. This is one of only three tasks for which those who enjoyed it very much were not in the majority. Those who reported performing this task spent an average of 22.1% of their time in project leading activities, with a mean satisfaction rating of 1.94. The only significant difference between those who enjoyed project leading very much and the others was higher scores on Finger Dexterity, which is not clearly related to this job task.

Technical consulting. Technical consulting involves being available to provide specific technical advice to other members of the group and to others within the company. Thirty-nine software engineers reported spending time engaged in this activity, 26 of whom reported enjoying it very much. Those engaging in technical consulting averaged 14.6% of their time on the task, with an average satisfaction rating of 1.44. Those who enjoyed technical consulting a great deal scored significantly higher in Foresight and lower in Finger Dexterity than those who enjoyed it less.

Performance modeling. Performance modeling is developing ways to predict, test, and measure performance of a system. Only three software engineers reported spending any time in this activity, so no analyses were performed.

Test development. Test development means writing and executing test programs and analyzing the results. Of the 16 software engineers who spent in this activity, 2 enjoyed it a great deal, 11 enjoyed it moderately, 2 disliked it moderately and 1 disliked it very much. No meaningful groups could be formed that would yield sufficiently large sample sizes, so no analyses were performed.

Technical leadership. Technical leadership involves working individually and through others to set technical product direction and then monitoring implementation. Eighteen software engineers spent some of their time on technical leadership, 12 of whom enjoyed it very much, the other 6 moderately. Both groups spent about 15% of their time in this activity. Those who enjoyed technical leadership a great deal were significantly more Objective on the Word Association test.

Mentoring/training. Twenty-eight software engineers were involved with mentoring and training, which is passing on technical expertise and product knowledge to others. Seventeen enjoyed this activity a great deal, 9 enjoyed it moderately, and 1 each disliked the activity moderately and very much, respectively. The 28 engineers averaged about 15% of their working time in this activity, with an average satisfaction level of 1.5. Those who enjoyed mentoring/training very much scored significantly lower on Analytical Reasoning and Mathematics Vocabulary than those who enjoyed it moderately or less.

Documentation review and input. Documentation review and input includes reviewing technical literature and reporting any relevant findings. Of the 21 software engineers who spent time in this activity, only 3 enjoyed it very much, 9 enjoyed it moderately, and 9 disliked it moderately. The group reported spending an average of 8.4% of their time in this activity and gave it the lowest overall satisfaction rating of the various job tasks, 2.29.

Because only three of the software engineers reported enjoying documentation review a great deal, we compared those who enjoyed the task at all (very much or moderately) with those who disliked it moderately. Then *t*-tests were run again comparing only those who reported moderate liking and disliking, to see if the same relationships were obtained.

Software engineers who reported enjoying documentation review at all scored significantly higher on English Vocabulary than those who disliked the task moderately. When the three who enjoyed the task very much were removed from the analysis, those who moderate liked this task averaged twenty percentile points higher on English Vocabulary, but the difference in means was not significant at the .05 level.

GENERAL SUMMARY AND CONCLUSIONS

The sample of 60 software engineers from Digital Equipment Corporation scored significantly higher than the Foundation's general testing population on fourteen of eighteen aptitude tests: Graphoria (clerical speed), Ideaphoria (flow of ideas), Inductive and Analytical Reasoning, Number Series and Number Facility, Structural Visualization (Wiggly Block and Paper Folding), Rhythm Memory, Memory for Design, Silograms (word learning), Number Memory, Tweezer Dexterity, and Word Association. They also averaged significantly higher than general Foundation examinees on Mathematics Vocabulary.

Comparisons between the software engineers and regular Foundation examinees who had pursued engineering or computer science majors found essentially the same differences, with the exceptions of Analytical Reasoning, Number Series, and Rhythm Memory, for which the differences in means were not significant. They were significantly higher than the engineering but not the computer science majors on the Graphoria test.

As the comparisons were narrowed to regular examinees who reported overall satisfaction with their work in engineering or computer fields, the number of differences diminished. The software engineers scored significantly higher than computer professionals reporting satisfaction with their work (mostly programmers, analysts, and technical support staff) only on Tweezer Dexterity and Word Association and significantly higher than engineers reporting satisfaction with their jobs only on Ideaphoria, Silograms, and English Vocabulary. In other words, the aptitudes of software engineers seem to be largely the same as those of other computer professionals and engineers: clerical speed, reasoning abilities, spatial ability, numerical abilities, and memory.

The relationships between the aptitude measures and levels of satisfaction with the software engineers' job activities were generally in the expected directions. For instance, those who most enjoyed debugging programs tended to score lower on Ideaphoria and higher on Number Memory than those who derived less enjoyment from this activity. Those who enjoyed technical leadership a great deal scored significantly more Objective than those who reported less enjoyment. Finally, those who reported enjoying documentation review and input at all averaged significantly higher on English Vocabulary than those who reported disliking the activity.

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Appendix A

Score Distributions for Digital Equipment Corporation Software Engineers

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Stem and leaf diagrams of percentiles, including mean and median scores:

Graphoria

0 .
1 . 005
2 . 000555
3 . 05
4 . 555
5 . 55555
6 . 0555555
7 . 0000005555555
8 . 00000555
9 . 0005999999999

Mean	65.85
Median	70
SD	25.90

Ideaphoria

0 . 55555
1 . 005
2 . 0000555
3 . 55
4 . 0055
5 . 005
6 . 5555
7 . 0000555
8 . 0000555555
9 . 000005555555999

Mean	60.28
Median	70
SD	31.65

Foresight

0 . 555
1 . 0055555
2 . 000055
3 . 0555
4 . 00005555
5 . 05555
6 . 00055
7 . 000555555555
8 . 000000555
9 . 0

Mean	50.08
Median	55
SD	26.10

Inductive Reasoning

0 . 55
1 . 00000555
2 . 05
3 .
4 . 05
5 . 000555555
6 . 005
7 . 000005555555
8 . 000000555
9 . 00005555555559

Mean	62.15
Median	70
SD	28.98

Analytical Reasoning

0 . 55555	
1 . 55	
2 . 005	
3 .	
4 . 05	
5 . 00000555	
6 . 0000555	
7 . 0555	
8 . 00000055	
9 . 0000005555555555599999	
Mean	66.42
Median	75
SD	29.71

Number Series

0 . 7	
1 . 26	
2 . 188	
3 . 44	
4 . 222	
5 . 222	
6 . 11111999999	
7 . 6666666	
8 . 3333333339999	
9 . 55555559999999	
Mean	69.68
Median	76
SD	26.02

Number Facility

0 . 555	
1 . 5	
2 . 55	
3 . 55555	
4 . 555	
5 . 00055	
6 . 005555	
7 . 0555555	
8 . 0000000555	
9 . 000000055555559999	
Mean	67.60
Median	75
SD	26.50

Structural Visualization

0 . 5	
1 . 0	
2 . 005	
3 . 55	
4 . 0000	
5 . 005	
6 . 00	
7 . 0000000555555	
8 . 00000555555	
9 . 0000055555555555599999	
Mean	72.17
Median	80
SD	24.80

Wiggly Block

0 . 555
1 .
2 . 055
3 . 555
4 . 00555555
5 . 0055
6 . 55
7 . 00000555
8 . 000000055555555
9 . 00555555999999

Mean	67.32
Median	75
SD	26.52

Paper Folding

0 .
1 . 3
2 . 00555
3 . 55
4 . 00055
5 . 055
6 . 55
7 . 00000055
8 . 00005555555
9 . 000000005555555599999999

Mean	72.67
Median	82.5
SD	25.22

Tonal Memory

0 . 555
1 . 00555
2 . 000555
3 . 00005555
4 . 00555
5 . 05
6 . 0005555
7 . 0000555
8 . 0055
9 . 0005555555599

Mean	54.97
Median	60
SD	30.13

Pitch Discrimination

0 . 555
1 . 00555
2 . 000005
3 . 00000555
4 . 0005
5 . 00555
6 . 055
7 . 005555
8 . 000555
9 . 00000000555555

Mean	55.08
Median	55
SD	30.47

Rhythm Memory

0 . 5
1 . 0555
2 . 005
3 . 0000055
4 . 0000555
5 . 55555
6 . 000
7 . 00
8 . 00000000005555555
9 . 00055555999

Mean	61.20
Median	65
SD	27.94

Memory for Design

0 . 5
1 . 5
2 . 05
3 . 0
4 . 0
5 . 0555
6 . 005
7 . 0000555599
8 . 00000555555
9 . 0000055555555555559999

Mean	74.65
Median	82.5
SD	25.33

Silograms

0 . 5
1 . 555
2 . 55
3 . 0
4 . 0055555
5 . 0000005555
6 . 0000005
7 . 0000055555
8 . 05555555
9 . 00000005559

Mean	63.23
Median	62.5
SD	23.42

Number Memory

0 .
1 . 5
2 . 05555
3 . 0555
4 . 0005
5 . 005
6 . 00005
7 . 00000055555
8 . 000055555
9 . 00000055555599999

Mean	68.92
Median	75
SD	24.78

Observation

0 . 5
1 . 0005
2 . 000000555
3 . 000
4 . 00000000
5 . 0000
6 . 0000000
7 . 0000000005
8 . 00000
9 . 000000599

Mean	53.55
Median	60
SD	26.81

Finger Dexterity

0 . 555555
1 . 0055555
2 . 0000055
3 . 0000555555
4 . 0000555555
5 . 0555
6 . 05555
7 . 005
8 . 0000055
9 . 9

Mean	40.90
Median	37.5
SD	25.25

Tweezer Dexterity

0 . 5
1 . 00
2 . 0
3 . 055555
4 . 0055555
5 . 000
6 . 00000555
7 . 00005555
8 . 005555555
9 . 000000055555599

Mean	65.55
Median	70
SD	25.13

Word Association

0 . 5
1 . 7
2 . 2
3 . 22222222
4 . 0007
5 . 55
6 . 22222
7 . 00000077777777777777
8 . 555555
9 . 22222222999

Mean	66.62
Median	77.5
SD	24.02

English Vocabulary		**Mathematics Vocabulary**	
0 . 5		0 .	
1 . 00555		1 .	
2 . 005555		2 .	
3 . 0555		3 . 0	
4 . 000055		4 .	
5 . 055555		5 .	
6 . 000555		6 . 5	
7 . 0000055555		7 . 00055	
8 . 00055555		8 . 000000055555555	
9 . 0055599		9 . 00000005555555555555555555555599999	
Mean	56.75	Mean	86.95
Median	60	Median	90
SD	26.64	*SD*	13.67

Appendix B

Composition of Comparison Groups

Groups:

Digital = Software engineers, Digital Equipment Corporation (*n* = 60)

Regular = Johnson O'Connor examinees, age 26-56, education 13+ years (*n* = 12,079)

Engineering:

Majors = Regular examinees (as above) who reported an engineering field as college major (major field codes [MFCs] 350-389)* (*n* = 505)

Occupation = Regular examinees (as above) who reported an engineering field as college major and reported an engineering field as their most recent occupation (occupation codes [OCs] 002-015)* (*n* = 59)

Satisfied = Regular examinees (as above) who reported an engineering field as college major and most recent occupation and reported liking their work (*n* = 17)

In computer field = Regular examinees (as above) who reported an engineering field as college major and reported a computer occupation (OCs 030-039)* as their most recent occupation (*n* = 18)

Computer Science:

Majors = Regular examinees (as above) who reported a computer science field as college major (MFCs 291-293, 298) (*n* = 193)

Occupation = Regular examinees (as above) who reported a computer science field as college major and reported a computer-related field as their most recent occupation (*n* = 31)

Satisfied computer occup. = Regular examinees (as above) who reported a computer science field as their most recent occupation and reported liking their work (*n* = 39)

* Codes used within the Johnson O'Connor Research Foundation.

Digital = Software engineers, Digital Equipment Corporation (n = 60)

Sex: 47 males (78.3%), 13 females (21.7%)
Mean age: 35.62 years
Mean education: 16.57 years
Mean father's education: 14.31 years
Mean mother's education: 14.12 years
Mean years in latest job: 5.4 years
College-major field codes:

	n	%
250 Business Administration	2	3.3
256 Engineering Management	1	1.7
270 Communications	1	1.7
293 Computer Science	37	61.7
310 Education (general)	1	1.7
359 Computer Engineering	6	10.0
361 Electrical Engineering	4	6.7
560 Mathematics	3	5.0
616 Chemistry	1	1.7
630 Physics	2	3.3
686 Sociology	1	1.7
902 Construction Trades	1	1.7

Regular = Foundation examinees, Age 26-56, Education 13+ years (n = 12,079)

Sex: 5,786 males (47.9%), 6,293 females (52.1%)
Mean age: 36.36 years
Mean education: 16.48 years
Mean father's education: 15.15 years
Mean mother's education: 14.05 years
Mean years in latest job: 4.42 years

Sources:

College major field codes: Test Information Bulletin 1989-7
Occupation codes: Test Information Bulletin 1992-4

Engineering majors = regular examinees (as above) who reported an engineering field as college major (major field codes 350-389) (*n* = 505)

Sex: 398 males (78.8%), 107 females (21.2%)
Mean age: 35.49 years
Mean education: 16.50 years
Mean father's education: 14.88 years
Mean mother's education: 14.02 years
Mean years in latest job: 4.59 years

College major field codes:	*n*	%
350 Engineering	44	8.7
351 Aerospace/Aeronautics Engineering	16	3.2
352 Agricultural Engineering	5	1.0
354 Audio/Sound Engineering	1	.2
356 Bioengineering/Biomedical Engineering	7	1.4
357 Chemical Engineering	32	6.3
358 Civil Engineering	57	11.3
359 Computer Engineering	12	2.4
360 Construction/Transportation Engineering	6	1.2
361 Electrical/Electronics Engineering	138	27.3
362 General Engineering	5	1.0
363 Industrial/Management Engineering	32	6.3
364 Manufacturing Engineering	2	.4
365 Marine/Naval Engineering	3	.6
366 Materials Engineering	2	.4
367 Mechanical Engineering	110	21.8
368 Metallurgical Engineering	6	1.2
369 Nuclear Engineering	2	.4
370 Petroleum/Natural Gas Engineering	3	.6
371 Systems Engineering	3	.6
389 Other Engineering, Specified	19	3.8

Sources:
College major field codes: Test Information Bulletin 1989-7
Occupation codes: Test Information Bulletin 1992-4

Engineering occupation = regular examinees (as above) who reported an engineering field as college major and reported an engineering field as their most recent occupation (occupation codes 002-015) (*n* = 59)

Sex: 42 males (71.2%), 17 females (28.8%)
Mean age: 32.92 years
Mean education: 16.47 years
Mean father's education: 15.26 years
Mean mother's education: 14.39 years
Mean years in latest job: 4.76 years

	n	%
Major field codes:		
350 Engineering	1	1.7
351 Aerospace/Aeronautics Engineering	6	10.2
357 Chemical Engineering	4	6.8
358 Civil Engineering	4	6.8
361 Electrical/Electronics Engineering	16	27.1
363 Industrial/Management Engineering	3	5.1
365 Marine/Naval Engineering	1	1.7
367 Mechanical Engineering	21	35.6
370 Petroleum/Natural Gas Engineering	1	1.7
389 Other Engineering, Specified	2	3.4
Occupation codes:		
002 Aeronautical Engineering	12	20.3
003 Electrical/Electronics Engineering	11	18.6
005 Civil Engineering	5	8.5
007 Mechanical Engineering	17	28.8
008 Chemical Engineering	2	3.4
010 Mining and Petroleum Engineering	4	6.8
012 Industrial Engineering	7	11.9
015 Nuclear Engineering	1	1.7

Sources:

College major field codes: Test Information Bulletin 1989-7
Occupation codes: Test Information Bulletin 1992-4

Satisfied engineers = regular examinees (as above) who reported an engineering field as college major and most recent occupation and reported liking their work (n = 17)

Sex: 13 males (76.5%), 4 females (23.5%)
Mean age: 34.65 years
Mean education: 16.18 years
Mean father's education: 15.53 years
Mean mother's education: 14.07 years
Mean years in latest job: 5.24 years

	n	%
Major Field Codes:		
351 Aerospace/Aeronautics Engineering	2	11.8
357 Chemical Engineering	1	5.9
358 Civil Engineering	2	11.8
361 Electrical/Electronics Engineering	3	17.6
365 Marine/Naval Engineering	1	5.9
367 Mechanical Engineering	6	35.3
370 Petroleum/Natural Gas Engineering	1	5.9
389 Other Engineering, Specified	1	5.9
Occupation codes:		
002 Aeronautical Engineering	3	17.6
003 Electrical/Electronics Engineering	4	23.5
005 Civil Engineering	1	5.9
007 Mechanical Engineering	6	35.3
010 Mining and Petroleum Engineering	1	5.9
012 Industrial Engineering	1	5.9
015 Nuclear Engineering	1	5.9

Sources:
College major field codes: Test Information Bulletin 1989-7
Occupation codes: Test Information Bulletin 1992-4

Engineers in computer field = regular examinees (as above) who reported an engineering field as college major and reported a computer occupation (OCs 030-039) as their most recent occupation (n = 18)

Sex: 13 males (72.2%), 5 females (27.8%)
Mean age: 36.22 years
Mean education: 17.39 years
Mean father's education: 15.47 years
Mean mother's education: 14.19 years
Mean years in latest job: 5.39 years

	n	%
Major field codes:		
350 Engineering	1	5.6
352 Agricultural Engineering	1	5.6
359 Computer Engineering	3	16.7
361 Electrical/Electronics Engineering	10	55.6
363 Industrial/Management Engineering	1	5.6
368 Metallurgical Engineering	1	5.6
371 Systems Engineering	1	5.6
Occupation codes:		
030 Systems Analysis & Programming	14	77.8
033 Computer Systems Technical Support	4	22.2

Computer science majors = regular examinees (as above) who reported a computer science field as college major (MFCs 291-293, 298) (n = 193)

Sex: 101 males (52.3%), 92 females (47.7%)
Mean age: 34.49 years
Mean education: 16.46 years
Mean father's education: 14.74 years
Mean mother's education: 13.66 years
Mean years in latest job: 4.05 years

Major Field Codes:	*n*	%
291 Computer Information Systems	18	9.3
292 Computer Programming	12	6.2
293 Computer Science	150	77.7
298 Management Information Systems	13	6.7

Sources:

College major field codes: Test Information Bulletin 1989-7
Occupation codes: Test Information Bulletin 1992-4

Computer science occupation = regular examinees (as above) who reported a computer science field as college major and reported a computer-related field as their most recent occupation (*n* = 31)

Sex: 18 males (58.1%), 13 females (41.9%)
Mean age: 33.39 years
Mean education: 16.52 years
Mean father's education: 14.37 years
Mean mother's education: 13.94 years
Mean years in latest job: 4.55 years

	n	%
291 Computer Information Systems	3	9.7
292 Computer Programming	1	3.2
293 Computer Science	25	80.6
298 Management Information Systems	2	6.5
Occupation codes:		
030 Systems Analysis & Programming	23	74.2
032 Computer System User Support	1	3.2
033 Computer Systems Technical Support	5	16.1
039 Computer Related, Not Elsewhere Classified	2	6.5

Sources:

College major field codes: Test Information Bulletin 1989-7
Occupation codes: Test Information Bulletin 1992-4

Satisfied Computer Occup. = regular examinees (as above) who reported a computer science field as their most recent occupation and reported liking their work (*n* = 39)

Sex: 30 males (76.9%), 9 females (23.1%)
Mean age: 38.03 years
Mean education: 17.13 years
Mean father's education: 15.34 years
Mean mother's education: 14.21 years
Mean years in latest job: 6.00 years

	n	%
Major Field Codes:		
107 Agricultural Economics	1	2.6
190 Biology	1	2.6
231 Accounting	2	5.1
234 Finance	1	2.6
250 Business Administration	6	15.4
260 Industrial Management	1	2.6
292 Computer Programming	1	2.6
293 Computer Science	9	23.1
309 Other Computer, Information & Library Science, specified	1	2.6
350 Engineering	1	2.6
359 Computer Engineering	1	2.6
361 Electrical/Electronics Engineering	2	5.1
431 Chiropractics	1	2.6
521 Classics	1	2.6
560 Mathematics	1	2.6
616 Chemistry	1	2.6
630 Physics	2	5.1
650 Psychology	2	5.1
687 Economics	2	5.1
689 Geography	1	2.6
Occupation codes:		
030 Systems Analysis & Programming	27	69.2
032 Computer System User Support	3	7.7
033 Computer Systems Technical Support	8	20.5
039 Computer Related, Not Elsewhere Classified	1	2.6

Sources:
College major field codes: Test Information Bulletin 1989-7
Occupation codes: Test Information Bulletin 1992-4

Appendix C

Percentile Means, Standard Score Means, Difference from Software Engineers' Means, and Significance of Difference for Comparison Groups

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The difference in *z*-score means between the Digital and comparison groups is shown in the third column. A negative difference indicates that the comparison group scored lower than the software engineers, while a positive difference indicates that the comparison group scored higher than the software engineers. The *p*-value for the Mann-Whitney *U* test for significance is shown in the fourth column.

	%ile mean	*z*-score mean	Diff. in means	*p*
GRAPHORIA				
Digital	65.85	.590	--	--
Regular	53.59	.155	-.435	.001
Engineering				
Majors	54.42	.170	-.420	.003
Occupation	54.59	.205	-.385	.034
Satisfied	55.53	.204	-.386	.158
In computer field	62.67	.465	-.125	.735
Computer Science				
Majors	60.03	.378	-.212	.149
Occupation	57.81	.342	-.248	.252
Satisfied computer occup.	64.44	.482	-.108	.880
IDEAPHORIA				
Digital	60.28	.359	--	--
Regular	52.26	.079	-.280	.032
Engineering				
Majors	50.26	.012	-.347	.012
Occupation	45.41	-.143	-.502	.010
Satisfied	39.71	-.319	-.678	.023
In computer field	64.61	.560	.201	.487
Computer Science				
Majors	50.51	.011	-.348	.020
Occupation	43.23	-.217	-.576	.016
Satisfied computer occup.	57.26	.280	-.079	.667

	%ile mean	*z*-score mean	Diff. in means	*p*
FORESIGHT				
Digital	50.08	-.026	--	--
Regular	54.86	.156	.182	.154
Engineering				
Majors	55.93	.181	.207	.122
Occupation	N/A	N/A	N/A	N/A
Satisfied	N/A	N/A	N/A	N/A
In computer field	N/A	N/A	N/A	N/A
Computer Science				
Majors	52.08	.078	.104	.674
Occupation	N/A	N/A	N/A	N/A
Satisfied computer occup.	N/A	N/A	N/A	N/A

(Note: Foresight administration discontinued at time occupational coding introduced.)

	%ile mean	*z*-score mean	Diff. in means	*p*
INDUCTIVE REASONING				
Digital	62.15	.384	--	--
Regular	53.68	.120	-.264	.017
Engineering				
Majors	52.36	.070	-.314	.011
Occupation	54.08	.107	-.277	.091
Satisfied	50.47	.015	-.369	.113
In computer field	41.94	-.254	-.638	.024
Computer Science				
Majors	53.59	.110	-.274	.039
Occupation	44.97	-.136	-.520	.005
Satisfied computer occup.	57.64	.291	-.093	.360

	%ile mean	*z*-score mean	Diff. in means	*p*
ANALYTICAL REASONING				
Digital	66.42	.588	--	--
Regular	54.05	.146	-.442	<.001
Engineering				
Majors	59.75	.348	-.240	.035
Occupation	65.81	.601	.013	.741
Satisfied	63.71	.498	-.090	.518
In computer field	66.94	.520	-.068	.544
Computer Science				
Majors	58.07	.288	-.300	.028
Occupation	52.71	.119	-.469	.021
Satisfied computer occup.	66.87	.615	.027	.765
NUMBER SERIES				
Digital	69.68	.706	--	--
Regular	56.63	.235	-.471	<.001
Engineering				
Majors	66.83	.591	-.115	.342
Occupation	69.69	.675	-.031	.871
Satisfied	70.18	.668	-.038	.758
In computer field	77.39	1.014	.308	.257
Computer Science				
Majors	68.30	.646	-.060	.801
Occupation	69.42	.708	.002	.920
Satisfied computer occup.	73.82	.900	.194	.445

	%ile mean	*z*-score mean	Diff. in means	*p*
NUMBER FACILITY				
Digital	67.60	.600	--	--
Regular	54.50	.148	-.452	<.001
Engineering				
Majors	62.52	.422	-.178	.118
Occupation	62.56	.447	-.153	.323
Satisfied	54.71	.129	-.471	.066
In computer field	64.11	.482	-.118	.402
Computer Science				
Majors	60.36	.331	-.269	.046
Occupation	60.81	.354	-.246	.214
Satisfied Computer Occup.	66.79	.528	-.072	.513
STRUCTURAL VISUALIZATION				
Digital	72.17	.770	--	--
Regular	41.23	-.287	-1.057	<.001
Engineering				
Majors	62.43	.411	-.359	.003
Occupation	64.66	.455	-.315	.045
Satisfied	62.94	.408	-.362	.123
In computer field	66.61	.559	-.211	.372
Computer Science				
Majors	53.41	.130	-.640	<.001
Occupation	57.10	.249	-.521	.006
Satisfied Computer Occup.	64.85	.493	-.277	.164

	%ile mean	*z*-score mean	Diff. in means	*p*
WIGGLY BLOCK				
Digital	67.32	.612	--	--
Regular	40.90	-.303	-.915	<.001
Engineering				
Majors	57.06	.231	-.381	.003
Occupation	64.66	.455	-.157	.045
Satisfied	59.12	.324	-.288	.225
In computer field	54.94	.168	-.444	.096
Computer Science				
Majors	49.73	.001	-.611	<.001
Occupation	54.84	.161	-.451	.015
Satisfied Computer Occup.	58.72	.270	-.342	.057
PAPER FOLDING				
Digital	72.67	.833	--	--
Regular	45.80	-.125	-.958	<.001
Engineering				
Majors	66.64	.550	-.283	.026
Occupation	68.62	.592	-.241	.142
Satisfied	64.35	.448	-.385	.117
In computer field	76.39	.867	.034	.807
Computer Science				
Majors	58.65	.288	-.545	<.001
Occupation	60.13	.352	-.481	.019
Satisfied Computer Occup.	68.85	.672	-.161	.548

	%ile mean	*z*-score mean	Diff. in means	*p*
TONAL MEMORY				
Digital	54.97	.205	--	--
Regular	51.72	.089	-.116	.392
Engineering				
Majors	53.34	.139	-.066	.653
Occupation	50.68	.010	-.195	.352
Satisfied	53.82	.135	-.070	.806
In computer field	61.94	.353	.148	.436
Computer Science				
Majors	53.80	.174	-.031	.813
Occupation	49.77	.050	-.155	.463
Satisfied Computer Occup.	53.15	.136	-.069	.810
PITCH DISCRIMINATION				
Digital	55.08	.180	--	--
Regular	51.07	.036	-.144	.242
Engineering				
Majors	55.08	.166	-.014	.867
Occupation	52.46	.073	-.107	.544
Satisfied	57.35	.217	.037	.922
In computer field	50.44	.099	-.081	.664
Computer Science				
Majors	54.54	.143	-.037	.826
Occupation	45.81	-.151	-.331	.150
Satisfied Computer Occup.	52.92	.108	-.072	.656

	%ile mean	*z*-score mean	Diff. in means	*p*
RHYTHM MEMORY				
Digital	61.20	.401	--	--
Regular	52.33	.082	-.319	.018
Engineering				
Majors	54.05	.147	-.254	.064
Occupation	52.44	.073	-.328	.066
Satisfied	58.24	.243	-.158	.609
In computer field	61.56	.418	-.017	.915
Computer Science				
Majors	58.65	.298	-.103	.547
Occupation	55.97	.185	-.216	.424
Satisfied Computer Occup.	59.49	.267	-.134	.695
MEMORY FOR DESIGN				
Digital	74.65	.852	--	--
Regular	53.16	.101	-.751	<.001
Engineering				
Majors	68.97	.634	-.218	.029
Occupation	72.66	.773	-.079	.402
Satisfied	67.94	.579	-.273	.176
In computer field	77.50	.842	-.010	.698
Computer Science				
Majors	61.89	.409	-.443	.001
Occupation	66.45	.539	-.313	.036
Satisfied Computer Occup.	76.33	.893	.041	.991

	%ile mean	*z*-score mean	Diff. in means	*p*
SILOGRAMS				
Digital	63.23	.416	--	--
Regular	52.27	.083	-.333	.003
Engineering				
Majors	49.54	-.015	-.431	<.001
Occupation	46.61	-.115	-.531	.001
Satisfied	41.76	-.287	-.703	.006
In computer field	63.06	.404	-.012	.762
Computer Science				
Majors	51.90	.093	-.323	.007
Occupation	53.03	.107	-.309	.115
Satisfied Computer Occup.	60.82	.401	-.015	.813
NUMBER MEMORY				
Digital	68.92	.672	--	--
Regular	51.03	.037	-.635	<.001
Engineering				
Majors	57.74	.261	-.411	.003
Occupation	62.58	.445	-.227	.147
Satisfied	55.29	.201	-.471	.056
In computer field	67.72	.648	-.024	.967
Computer Science				
Majors	57.27	.253	-.419	.007
Occupation	53.39	.108	-.564	.018
Satisfied Computer Occup.	65.97	.539	-.133	.457

	%ile mean	*z*-score mean	Diff. in means	*p*
OBSERVATION				
Digital	53.55	.136	--	--
Regular	52.64	.087	-.049	.841
Engineering				
Majors	53.89	.123	-.013	.883
Occupation	55.27	.194	.058	.658
Satisfied	55.88	.178	.042	.666
In computer field	45.00	-.168	-.304	.287
Computer Science				
Majors	53.85	.118	-.018	.867
Occupation	46.61	-.126	-.262	.255
Satisfied Computer Occup.	52.13	.032	-.104	.813
FINGER DEXTERITY				
Digital	40.90	-.281	--	--
Regular	46.77	-.109	.172	.122
Engineering				
Majors	44.14	-.195	.086	.446
Occupation	49.31	-.018	.263	.107
Satisfied	53.24	.098	.379	.482
In computer field	52.50	.054	.335	.142
Computer Science				
Majors	47.94	-.067	.214	.126
Occupation	41.29	-.279	.002	.873
Satisfied Computer Occup.	42.31	-.259	.022	.782

	%ile mean	*z*-score mean	Diff. in means	*p*
TWEEZER DEXTERITY				
Digital	65.55	.517	--	--
Regular	50.09	.003	-.514	<.001
Engineering				
Majors	56.09	.205	-.312	.013
Occupation	59.64	.310	-.207	.195
Satisfied	61.41	.398	-.119	.555
In computer field	73.56	.747	.230	.347
Computer Science				
Majors	49.67	.004	-.513	<.001
Occupation	48.13	-.023	-.540	.009
Satisfied Computer Occup.	53.82	.146	-.371	.020
WORD ASSOCIATION				
Digital	66.62	.541	--	--
Regular	49.53	-.058	-.599	<.001
Engineering				
Majors	49.47	-.061	-.602	<.001
Occupation	53.18	-.065	-.606	.013
Satisfied	58.82	.247	-.294	.373
In computer field	48.06	-.132	-.673	.002
Computer Science				
Majors	53.46	.055	-.486	.002
Occupation	49.44	-.138	-.679	.017
Satisfied Computer Occup.	56.15	.109	-.432	.034

	%ile mean	*z*-score mean	Diff. in means	*p*
ENGLISH VOCABULARY				
Digital	56.75	.233	--	--
Regular	46.12	-.106	-.339	.003
Engineering				
Majors	43.62	-.181	-.414	<.001
Occupation	38.90	-.338	-.571	<.001
Satisfied	33.24	-.507	-.740	.002
In computer field	55.78	.170	.063	.838
Computer Science				
Majors	45.09	-.138	-.371	.003
Occupation	42.42	-.227	-.460	.016
Satisfied Computer Occup.	59.18	.338	.105	.746

Note. The sample of software engineers could not be compared to the various Foundation groups on the Mathematics Vocabulary test because that test is not administered to Foundation examinees in the relevant age range (26-56).

Appendix D

Comparison of Male Software Engineers and Male Regular Examinees

	Digital mean	Regular examinee mean
N	47	5,786
Age	35.98	36.04
Education	16.53	16.61
Father's education	14.26	15.10
Mother's education	14.02	14.01
Years in latest job	5.87	4.97

	Percentile means		*Z*-score means		
Test	Digital	Regular	Digital	Regular	*p*
Graphoria	64.53	48.74	.55	-.01	<.001
Ideaphoria	61.53	52.05	.42	.07	.024
Foresight	50.85	55.66	-.01	.18	.194
Inductive Reasoning	61.36	51.55	.36	.05	.019
Analytical Reasoning	65.13	53.32	.55	.12	.003
Number Series	67.79	57.89	.64	.28	.009
Number Facility	66.62	54.70	.58	.16	.003
Structural Visualization	71.92	48.11	.78	-.06	<.001
Wiggly Block	67.12	47.90	.62	-.08	<.001
Paper Folding	72.79	50.72	.85	.03	<.001
Tonal Memory	54.55	50.32	.18	.05	.345
Pitch Discrimination	54.79	53.20	.17	.11	.607
Rhythm Memory	61.43	52.24	.42	.08	.032
Memory for Design	73.85	55.06	.83	.17	<.001
Silograms	62.45	46.08	.38	-.12	<.001
Number Memory	66.94	50.68	.62	.03	<.001
Observation	54.96	48.07	.18	-.06	.096
Finger Dexterity	36.17	34.79	-.44	-.50	.540
Tweezer Dexterity	64.96	50.23	.52	.00	<.001
Word Association	65.68	50.91	.52	-.01	<.001
English Vocabulary	55.61	45.64	.20	-.12	.015