Relationships of Admissions Data and Measurements of Psychological Constructs with Psychomotor Performance of Dental Technology Students

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Abstract: The psychomotor skills required in dental laboratory technology and dentistry are similar. Dental educators have recognized the problems in selecting from among dental school applicants those with potential psychomotor skills. The purpose of this study was to examine the relationships of admissions data and measurements of psychological constructs of dental technology students with their psychomotor performance in first-semester dental laboratory courses. The dependent variables selected for the study were grades from three laboratory courses. Significant positive correlations (p<.05) were noted between all laboratory grades and previous college hours, previous college GPA, interview scores, field dependence-independence scores, block counting, trust, straightforwardness, and dutifulness. These data indicate that individual differentiation in learning ability, visual or spatial perception, and personality do affect psychomotor learning and should be taken into consideration in the design and execution of teaching and training curricula.

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Key words: dental laboratory technology, psychomotor skills, personality, spatial ability, dental education

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Acquisition of psychomotor skills is one of the most important educational objectives in dental education. Also called sensorimotor or perceptual-motor skills, psychomotor skills are studied as special topics in the experimental psychology of learning and performance. Despite theoretical and empirical progress, much remains to be understood about the acquisition of psychomotor skills and their interrelationship with human-factor variables. The purpose of this study was to examine the relationships of admissions data and measurements of psychological constructs of dental technology students with their psychomotor performance in first-semester dental laboratory courses.

During their two-year program, students in the Department of Dental Laboratory Technology at the University of Texas Health Science Center at San Antonio (UTHSCSA) take laboratory courses that require psychomotor skills. Since the curriculum is sequential, satisfactory completion of the first-semester laboratory courses is necessary to remain enrolled in the program. Entering students generally conform to one of three broad scenarios:

1. A student has adequate psychomotor skills at the beginning of the first semester, and performs satisfactorily in first-semester dental laboratory courses.
2. A student has inadequate psychomotor skills at the beginning of the first semester, but develops adequate skills and performs satisfactorily in first-semester dental laboratory courses.
3. A student has inadequate psychomotor skills at the beginning of the first semester, but does not develop adequate skills and has difficulty in performing satisfactorily in first-semester dental laboratory courses.

Students who conform to the first scenario are easily identified at the beginning of the semester by their performance on psychomotor tests and/or early laboratory projects. However, it may take several weeks into the semester before the scenario of the remaining students can be identified. Unfortunately, those students in the third scenario are likely to be dropped from the program due to unsatisfactory laboratory performance.
Prior to 1991, student selection at the UTHSCSA was based on previous high school and college grade point averages (GPA), interview scores, and performance on a wax version of the American Dental Association Chalk Carving Test. GPA scores identified candidates with good academic ability who were likely to perform well in didactic courses. The wax carving test identified candidates with good psychomotor skills who were likely to perform well in laboratory courses. A problem with the wax carving test is that it measures only existing psychomotor skills. It is not intended to predict the eventual skill acquisition of individuals with low scores. Because of cost, time requirements, predictive limitations, and small applicant pools, the wax carving test was deleted from the departmental selection process in 1991. However, the need for better predictors of psychomotor skill potential remained.

The psychomotor skills required in dental laboratory technology and dentistry are very similar. Both disciplines require motor skills that involve the manipulation of small hand-held instruments using precise movements of the fingers, hands, and wrists. The dentist and technician must be able to accurately perceive shapes, contours, proportions, and symmetry in three dimensions. Dental educators have recognized the problems in identifying those dental school applicants with the potential to develop psychomotor skills necessary for providing dental care.1 While only two psychomotor studies were found that dealt specifically with dental laboratory technology,2,3 more than 200 studies have been documented in dental education. Generally, these investigators have used admissions data including predental GPA, the Dental Admissions Test (DAT) scores, dexterity tests, and interviews as predictor variables in dental school performance studies. Several researchers have investigated the predictive value of measures derived from psychological constructs including field dependence-independence (FDI),4-6 spatial ability,7-15 and personality.16-25

While dental investigators have reported success in predicting overall dental school performance, predicting preclinical and clinical performance involving psychomotor skills has been more difficult. This difficulty appears to be caused by: 1) restricted ranges of predental GPA, preclinical grades, and clinical grades; 2) low reliability of preclinical and clinical grades; and 3) subjective evaluations.8,9,26

Methods

The population used in this study consisted of dental laboratory technology students who completed the fall semester from 1994 through 1997 (N = 80). The average age of the participant was twenty-nine with a range of nineteen to fifty-nine. There were forty-eight males and thirty-two females. The ethnic groups and numbers were White (thirty-four), Hispanic (twenty-two), Black (two), Asian (eighteen), and Middle Eastern (four). Eleven students did not complete the semester and were dropped from the study. Participation in the study was voluntary, and all students in each class chose to participate.

The dependent and independent variables used were selected from those documented in dental research.

Dependent Variables

The four dependent variables selected for the study were grades from three laboratory courses offered in the first semester and their combined average. The courses were: complete dentures, removable partial dentures, and crown and bridge. Courses in ceramics and orthodontics are presented in the second semester. During their final year, students are required to specialize in two of the five dental laboratory areas. Therefore, the investigators were interested in relationships between independent variables and performance in specific laboratory areas.

Although the laboratory courses involved different subject areas and were taught by different faculty members, they were alike in many ways. Similar psychomotor skills were required to fabricate projects. Based on points earned from the projects, interval course grades ranging from zero to one hundred were assigned. Each laboratory course met for six clock hours per week during the semester. The same teaching laboratory was used. Since there was only one section for each course, all students were exposed to essentially the same learning environment. The faculty, laboratory projects, and format of each course remained constant during the years of the study.
Independent Variables

Admissions data. Prior to being admitted into the dental laboratory technology program, the subjects completed an application form, provided college and high school transcripts, and were interviewed by two faculty members. Gender, age, ethnicity, college hours, college GPA, and interview scores were selected from these data and used as independent variables.

Field dependence-independence (FDI). The Embedded Figures Test (EFT)\(^27\) was chosen to measure FDI. The EFT is a visual perception test that measures the individual’s competency in disembedding. It is an individually administered test that requires the subject to find simple geometrical figures that are embedded in more complex geometrical fields. The subject is given a short period of time in which to study and memorize a simple figure printed on a small card. The study card is then removed from sight, and the subject is shown a card with a printed field containing that figure. The subject is required to locate the figure. This process is repeated with different figures and fields. FDI is measured by the average time required to solve several problems. Faster times indicate field independence while slower times indicate field dependence. Figure 1 contains a figure and field similar to those used in the EFT.

Personality. The NEO-PI-R: Form S\(^28,29\) was selected to measure personality. The NEO-PI is a self-administered inventory that measures five personality domains and six facets of each domain. These five domains and facets are: 1) neuroticism (anxiety, angry hostility, depression, self-consciousness, impulsiveness, vulnerability); 2) extroversion (warmth, gregariousness, assertiveness, activity, excitement-seeking, positive emotions); 3) openness (fantasy, aesthetics, feelings, actions, ideas, values); 4) agreeableness (trust, straightforwardness, altruism, compliance, modesty, tender-mindedness); and 5) conscientiousness (competence, order, dutifulness, achievement striving, self-discipline, deliberation).

The subject is required to respond to 240 questions about his or her personality by answering “strongly disagree,” “disagree,” “neutral,” “agree,” or “strongly agree.” The raw scores from the domain and facets were used to measure personality.

Spatial ability. Three instruments were selected to measure spatial ability. They were 1) the Revised Minnesota Paper Form Board Test (RMPFBT)\(^30\) and the 2) Dimensions and 3) Blocks tests of the IPJ Job-Test Program.\(^31\)

The RMPFBT requires the subject to study sets of geometrical shapes. Each set contains one disassembled shape and five assembled shapes. Assembling the disassembled shapes can form only one of the five assembled shapes. By mental manipulation, the subject is required to select the correct assembled shape. The total number of correct selections within the allotted time determines the score. Figure 2 represents a problem similar to those used in the RMPFT.

The Blocks test requires the subject to count the number of blocks contained in stacks of blocks. Each problem contains a three-dimensional drawing of a stack of blocks. The subject is required to count the total number of blocks seen and hidden from view. The number of stacks counted correctly within the allotted time determines the score. Figure 3 represents a problem similar to those used in the RMPFT.

Figure 2. RMPFT problem

Figure 3. Blocks test problem
The Dimensions test requires the subject to examine sets of five printed objects. Within each set, four of the objects are identical. The fifth object is the mirror image of the other four. The subject is required to identify the mirror image object within each set. The correct number of objects identified within the allotted time determines the score. Figure 4 represents a problem similar to those used in the Dimensions test.

Data Collection and Analyses

The admissions data were compiled from the student’s application materials. These included an application form, official transcripts, and interview evaluations from two faculty members.

Orientation and lecture classes were scheduled for the first week of the semester. Since laboratory courses did not start until the second week, the personality and spatial ability tests were administered during the first week of the semester. Because of time requirements, the EFT was given later in the semester. Since FDI is a stable construct, it was assumed that giving the EFT after exposure to laboratory work did not influence the test scores. The course grade data were collected from the course directors at the end of each semester.

One of the investigators (who carefully followed instructions provided in the test manuals) administered and graded all tests. The personality and spatial ability tests were given in group settings in a lecture room. The EFT was administered individually in a small conference room. The data, consisting of four dependent variables and forty-five independent variables, were placed in computer databases for analysis.

A correlational matrix was constructed with the independent variables and the dependent variables. The independent variables that produced significant correlations ($p < .05$) with one or more dependent variables were included in stepwise multiple regression analyses with grades from each course and with the average grades from all courses. The independent variables were entered at the .05 level of significance.

Results

From the correlational matrix of all variables, fourteen of the forty-five independent variables formed significant correlations with at least one measure of laboratory performance. Of the six admission variables, previous college hours, previous college GPA, and interview had significant positive correlations with each laboratory grade. Five of the psychological variables formed significant correlations with each of the dependent variables. The Blocks test and the personality variables of trust, straightforwardness, and dutifulness had positive correlations. The EFT had negative correlations. Five other personality variables had significant positive correlations with at least one measure of laboratory performance. These were warmth, agreeableness, compliance, conscientiousness, and deliberation. Excitement-seeking had negative correlations. The strength of the significant correlations is given in Table 1.

Age, gender, and ethnicity did not form significant correlations with any dependent variable. Although female students outperformed male students in every course, the differences were not significant. Except for Middle Eastern students, Asian students scored significantly higher in partial dentures than the other ethnic groups. No significant ethnic differences were noted among the other dependent variables.

Male students scored significantly higher than female students on the RMPFBT and the Dimensions test. Significant gender differences were noted among the personality variables. Male students were more impulsive while female students were more warm, agreeable, trusting, straightforward, altruistic, tender-minded, self-disciplined, and positive in emotions.

The EFT, RMPFBT, and NEO-PI included normative data with the test materials. According to the
EFT norms, the dental laboratory students were more field independent than traditional college students. The dental laboratory students averaged 38.78 seconds per problem while the traditional student averaged 57.52 seconds. Similar results were found with the RMPFBT. The dental laboratory students averaged 44.41 correct problems while the traditional college student averaged 33.20. The average personality measures for the dental laboratory students according to gender were within the average ranges given in the normative data.

The fourteen independent variables that had significant correlations with at least one dependent variable were used in stepwise multiple regression analyses with each dependent variable. The results are given in Table 2. Previous college GPA and the Blocks test scores were the most consistent predictors among the independent variables. Blocks were selected first for partial and complete dentures, and second for crown and bridge and average. Previous college GPA was chosen first for crown and bridge and average, second for complete dentures, and third for partial dentures. Dutifulness was selected third for complete dentures and average. EFT was chosen fourth for partial dentures. Warmth was the third variable chosen for crown and bridge.

### Discussion

The correlation of previous college GPA with all laboratory grades and subsequent early selection in each of the stepwise multiple regression analyses support the findings in dentistry that GPA at the previous educational level is the single best predictor of overall dental school performance. However, researchers noted that GPA was less effective in predicting only preclinical or clinical performance. They attributed lower GPA correlations with preclinical and clinical grades to restricted ranges in previous GPA, preclinical and clinical grades, educational background, aptitude, and interest. Others reasoned that subjective evaluations in preclinical and clinical courses also lowered correlations.

<table>
<thead>
<tr>
<th>Course Grades</th>
<th>Partial Dentures</th>
<th>Complete Dentures</th>
<th>Crown &amp; Bridge</th>
<th>Average</th>
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</thead>
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<tr>
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<td>.338</td>
<td>.335</td>
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<td>Psychological Variables</td>
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<tr>
<td>EFT</td>
<td>-.345*</td>
<td>-.299*</td>
<td>-.243*</td>
<td>-.300*</td>
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<tr>
<td>Blocks</td>
<td>.401</td>
<td>.384</td>
<td>.342</td>
<td>.400</td>
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<tr>
<td>Warmth</td>
<td>.244</td>
<td></td>
<td>.269</td>
<td>.236</td>
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<tr>
<td>Excitement-Seeking</td>
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<td></td>
<td>-.226</td>
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<td>Agreeableness</td>
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<td>Trust</td>
<td>.249</td>
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<td>Straightforwardness</td>
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<td>Compliance</td>
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<td>Conscientiousness</td>
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<tr>
<td>Dutifulness</td>
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<td>.238</td>
<td>.248</td>
<td>.269</td>
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<tr>
<td>Deliberation</td>
<td>.226</td>
<td></td>
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</tbody>
</table>

* Negative correlation with field dependence

| Table 2. Stepwise multiple regression analyses using selected variables as predictors of laboratory grades |
|-----------------------------------------------|------------------|-----------------|
| Step | Variable Entered* | R | R² |
|------------------|------------------|-----------------|
| Partial Dentures | Blocks | .401 | .160 |
| 2 Conscientiousness | .517 | .267 |
| 3 GPA | .569 | .324 |
| 4 EFT | .648 | .361 |
| Complete Dentures | Blocks | .384 | .147 |
| 2 GPA | .483 | .233 |
| 3 Dutifulness | .530 | .281 |
| Crown & Bridge | GPA | .428 | .184 |
| 2 Blocks | .501 | .251 |
| 3 Warmth | .549 | .301 |
| Average | GPA | .420 | .176 |
| 2 Blocks | .529 | .280 |
| 3 Dutifulness | .582 | .339 |

*Variable entered at the .05 level of significance.
Restricted ranges in previous college GPA and laboratory grades were not a problem in this study. Previous college GPA ranged from .92 to 4.00 and the range of dental laboratory course grades averaged 57. Subjectivity cannot be completely eliminated in evaluating laboratory and clinical performance. Attempts were made in the laboratory courses to evaluate projects objectively. For each project, the student had access to written objectives, fabrication standards, detailed grade sheets based on objectives and standards, work samples, and instructor demonstrations.

Previous college hours had significant positive correlations with all dependent variables. Individuals with numerous college hours have demonstrated the ability to learn. They have attributes that are related to learning including intelligence, self-discipline, study skills, work ethic, and persistence. These attributes are important in all learning domains including the psychomotor domain. In aging studies outside of dentistry, investigators have noted significant positive correlations between educational level and psychomotor ability.35-38 Because of range restrictions, previous college hours are not normally used as predictor variables in dental school studies. The range in previous college hours for this study was from zero to 224.

The admission interview instrument used in this study was a four-point Likert scale rating of six areas including: first impression, motivation, knowledge of profession, communication skills, academic competency, and maturity. Significant positive correlations were found between interview scores and each grade. These findings are consistent with results reported in dentistry where investigators documented significant relationships between interview instruments and school performance, including preclinical and clinical grades.9,39-42 A survey conducted in 1980 found that interviews were considered by dental educators as the third most useful admissions instrument, following preprofessional GPA and DAT scores.9 Interviews collect information relating to motivation, self-appraisal, maturity, ability to relate, adaptability, principles or ethics, sense of responsibility, and personal reaction. The interview may be the only way to discover certain personal factors that may impact school performance.

Significant negative correlations were found between the EFT scores and laboratory grades. The EFT measures the time required to solve the visual problems. Faster times (i.e., lower scores) indicate field independence, and slower times indicate field dependence. Therefore, field-independent students performed better than field-dependent students in the laboratory courses. These findings support those reported in two dental studies by Suddick et al. in which significant positive correlations were found between field independence and performance in preclinical and clinical courses.4,5 In these studies, EFT scores gave higher correlations than DAT predictors. Especially strong correlations were noted between EFT and preclinical/clinical courses with students whose previous GPAs were below average, particularly in the sciences. The strength of the correlations increased as the student advanced through the years of the curriculum. In another dental investigation, no significant correlations were noted with field independence.6 Field independence was, however, significantly related to two-dimensional and three-dimensional scores on the perceptual-motor ability test. The investigators suggested that the restricted grade ranges of the dental courses accounted for the low correlations.

FDI is a mode of perceiving a field or complex system.32 In a field-dependent mode of perceiving, perception is strongly dominated by the overall organization of the surrounding field, and parts of the field are experienced as “fused.” In a field-independent mode of perceiving, parts of the field are experienced as discrete from the surrounding field. The general consensus among researchers outside of dentistry has been that field-independent individuals perform better in fields requiring specific attributes (mathematics, engineering, medicine, dentistry) than field-dependent individuals who perform better in fields requiring diverse attributes (social science, liberal arts, business, teaching).27,32,41,44

Prostheses fabricated by dental technicians are, for the most part, complex systems. A field-dependent individual will have more difficulty perceiving the specific relationship of individual parts to the whole prosthesis than will a field-independent individual. Likewise, the field-dependent individual will have difficulty in sensing the completed prosthesis while assembling the parts.

Significant positive correlations occurred between all laboratory grades and spatial ability represented by scores on the Blocks test. The concept of spatial ability used in this study is the ability to keenly perceive shapes, contours, proportions, and symmetry and utilize these mental images in the fabrication of laboratory projects. Dental investigators docu-
mented that spatial ability is strongly related to dental school performance, especially in preclinical and clinical courses.\textsuperscript{1,5,7,9,11-14,45}

Spatial ability is a complicated construct. Various types of spatial abilities have been identified. Only two types were used in this study. The RMPFBT and the Dimensions test measure the ability to mentally move two-dimensional objects. The Blocks test measures the spatial ability to visualize and count identically shaped, three-dimensional objects that are concealed in an ordered stack of the objects. More research is needed about the kinds of spatial abilities as they relate to various laboratory and clinical activities.

Nine of the thirty-five (five domain and thirty facets in the five domains) personality traits had significant correlations with at least one grade. Table 3 lists and describes the nine personality traits that correlate with dental laboratory technology student performance.\textsuperscript{29} Spurious correlations and “significant correlations” where none exist may result when an excessive number of independent variables are used. If this were the case, the correlations would have been more randomly formed among the personality traits. However, only two personality domains (agreeableness and conscientiousness) contained seven of the traits. Also, Costa and McCrae noted that warmth is closely related to the agreeableness domain.\textsuperscript{29}

The descriptions of the personality traits are applicable to the learning environment in which the study was conducted. Laboratory classes were small and informal. Two instructors per class provided ample opportunity for individualized instruction. Peer instruction (though not encouraged because of the precise nature of laboratory procedures) was common. Typically, strong friendships developed among the students. Faculty became true mentors for the students. Therefore, personality traits such as warmth, agreeableness, trust, straightforwardness, and compliance enhanced performance in this environment.

Industrial psychologists have suggested that conscientiousness is a personality trait that very closely relates to success in almost every field.\textsuperscript{46} In addition, they have suggested that conscientiousness is related to student traits of organization, persistence, and purposefulness.\textsuperscript{29} The precise and tedious nature of dental laboratory work requires a strong will, determination, deliberation, caution, punctuality, reliability, and care on the part of the dental technician. In light of these descriptions, the significant negative correlation with excitement seeking is logical.

The use of personality measures in dental school admission decisions has been limited and mixed results have been reported. Several investigators have used the Myers-Briggs Type Indicator (MBTI) in correlational studies with dental school performance.\textsuperscript{17-21,25,47} These scholars found that personality traits such as introversion-extroversion correlate mainly with clinical performance involving patient interaction.

### Conclusion

In student selection for dental laboratory technology programs, existing psychomotor skills are not the absolute predictor of laboratory performance. At the time of selection, applicants may have undeveloped psychomotor skills and not be selected because of performance on a psychomotor test. Correlates to psychomotor skill are needed to identify those applicants who will or will not develop adequate skills. This study confirmed the effectiveness of traditional predictors such as GPA and interview scores. Field independence (Embedded Figures Test) and spatial ability (Blocks test) proved to be strong predictors. Certain personality traits (NEO-PI) showed good potential as predictors. Differentiation in constructs studied in this study as well as learning ability, learning style, and performance strategies affect psycho-

<table>
<thead>
<tr>
<th>Personality Trait</th>
<th>Description of High Scorers</th>
</tr>
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<tbody>
<tr>
<td>1. Excitement-Seeking</td>
<td>High scorers enjoy thrills, sensations, and noisy environments and consider the lifestyle of low scorers boring.</td>
</tr>
<tr>
<td>2. Warmth</td>
<td>High scorers are affectionate, friendly, and form close attachments to others.</td>
</tr>
<tr>
<td>3. Agreeableness</td>
<td>The agreeable person is altruistic, sympathetic, cooperative, and helpful.</td>
</tr>
<tr>
<td>4. Trust</td>
<td>High scorers believe that others are honest and well intended.</td>
</tr>
<tr>
<td>5. Straightforwardness</td>
<td>High scorers are frank, sincere, and ingenuous.</td>
</tr>
<tr>
<td>6. Compliance</td>
<td>In response to conflict, high scorers defer to others, inhibit aggression, and forgive and forget.</td>
</tr>
<tr>
<td>7. Conscientiousness</td>
<td>High scorers are purposeful, strong-willed, determined, scrupulous, punctual, and reliable.</td>
</tr>
<tr>
<td>8. Dutifulness</td>
<td>High scorers adhere to their ethical principles and scrupulously fulfill their moral principles.</td>
</tr>
<tr>
<td>9. Deliberation</td>
<td>High scorers are cautious, deliberate, and think carefully before acting.</td>
</tr>
</tbody>
</table>
motor learning and should be taken into consideration in the design and execution of teaching and training curricula. Although curriculum design and instructional strategies were beyond the scope of this study, significant research has been conducted by Feil in which learning theory was applied in preclinical and clinical settings. The latter studies might be of interest to those involved in laboratory, preclinical, and clinical instruction.

REFERENCES