The Predictive Utility of Computer-Simulated Exercises for Preclinical Technique Performance


Abstract: The objective of this research was to determine if a computerized simulated dental exercise predicts students' subsequent performance in preclinical technique courses. Twenty-nine first-year dental students voluntarily participated in the investigation prior to their first experience with a dental handpiece. These students prepared an ideal Class I amalgam on an ivorine mandibular first molar tooth after viewing ten-minute videotaped instructions. Students completed the Class I amalgam on a computerized dental treatment simulator (SIM). All participants' SIM scores were correlated with sub-test scores of the Dental Admission Test (DAT), predental overall grade point average (GPA), predental Biology/Chemistry/Physics grade point average (BCP), and grades from the first two preclinical laboratory technique courses (Lab 1 and Lab 2). The results showed a significant correlation between the simulator scores and DAT sub-test scores of Academic Average and Total Science, as well as Lab 1 scores. Based on these results, the simulator appears to be a good measure of general cognitive ability, including cognitive ability required to complete uncomplicated preclinical exercises.

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Many professions are developing computer-simulated exercises to train students or to try to predict success on task performances. Many of these simulations have shown a high degree of validity and reliability. Lentz et al. in the obstetrics and gynecology literature have shown that surgical bench laboratory tasks can assess residents’ surgical skills with good reliability and validity. O’Connor and McGraw developed objective assessment instruments (check-lists) for use in suturing and endotrachael intubation psychomotor skill training and to test the instruments for inter-observer reliability. Neiman developed a systematic training program to assist young music students to acquire basic motor skills essential for conducting. Gyntelberg et al. have shown that computerized coordination ability testing can be used with a high degree of reliability and validity for predicting skills in occupational medicine. Tasi and Heinrichs developed reliable and valid simulated exercises that mimicked the eye-hand coordination tasks inherent in a laboratory video-endoscopic surgical environment. Prior to 1974 a sub-test called the Manual Average score, the average of the Spatial Relations score and the Chalk Carving score, was part of the Dental Aptitude Test (currently Dental Admission Test, DAT). The use of the Chalk Carving sub-test in predicting dental student performance was controversial among dental researchers. Chen et al., in their factorial investigation, concluded that the Chalk Carving test was not a measure of “digital dexterity” and had little value in the prediction equation of performance. Fernandez-Pabon supported this conclusion. Zullo, in his investigation of perceptual and motor abilities in dental students, confirmed the construct validity of the Chalk Carving test—that is, its capability in measuring a “small instrument dexterity factor.” In those studies, spatial relations and chalk carving were considered to be noncognitive in nature. Dworkin, in his study of the Dental Aptitude Test as a performance predictor over four years in
dental school, found a strong correlation between the DAT manual average and the freshman technique average.9 The DAT manual average had a stronger correlation with students’ grades in freshman technique courses than the spatial relations and carving dexterity tests. Other studies have shown a modest degree of correlation between the spatial relations score and dental student performance in preclinical laboratory courses.10 Because the reliability and validity of the chalk carving test were so controversial as a predictor of dental student performance, it was deleted as a component of the DAT in 1974.

Since 1974, the Perceptual Ability Test (PAT), a sub-test of the DAT, has been used by most dental schools as one of its primary admission criteria, in lieu of manual dexterity, perceptual speed, and psychomotor skill tests. More recently, dental schools have used computerized dental simulators in an effort to decrease the amount of time necessary for students to achieve an acceptable performance level.11 Although there is abundant literature describing the benefits of cognitive simulations in dentistry, few studies have explored the use of dental simulators for the development of technical skills. A study performed by Clancy et al. failed to show that a simulation clinic better prepares students for fixed prosthodontic tooth preparations than traditional teaching methods.12

Theoretically, a well-designed computerized simulated exercise should test both general cognitive abilities and the needed noncognitive components of perceptual speed, limited by neurological anatomy and physiology, and psychomotor skills. This information should enable dental educators to predict student performance in dental school.

The distinction between controlled and automatic processing, predicated on the consistency of information-processing demands, has been well documented in the experimental psychology literature. This schema depends on relations between stimuli and responses. Automatic processing that results from consistent stimulus-to-response skill acquisition is highly dependent on practice (repetition of task). Individual differences in cognitive and noncognitive determinants are less important once the skill has been learned. Controlled processing, inconsistent stimulus-to-response skill acquisition has little to no dependence on practice, but depends primarily on individual general and task-relevant broad-content abilities (cognitive determinants).13

**Hypothesis**

It is our contention that the DAT sub-test scores, the Biology/Chemistry/Physics grade point average (BCP), and the overall GPA measure cognitive abilities, albeit different determinants, and are devoid of tests for manual dexterity and the noncognitive components of perceptual speed and psychomotor skills (manual dexterity). Preclinical technique courses (Lab 1 and Lab 2) involve both cognitive determinants (controlled processing) and noncognitive determinants (perceptual speed and manual dexterity).

Assuming the cognitive determinants of the variables considered are directly related to, and comparable to, the cognitive components of the computerized simulated exercise test scores, variations in performance based on final computerized simulated exercise test scores should reflect the noncognitive abilities of speed processing and psychomotor skills. Results should reveal which of the components of psychomotor speed and perceptual ability, cognitive or noncognitive, is more important in predicting performance. Participants with low cognitive determinant scores (DAT, GPA, BCP) and high computerized simulated exercise test scores (cognitive and noncognitive) would indicate a dominance of the noncognitive speed processing and psychomotor skills components. Participants with high cognitive determinant scores and low computerized simulated exercise test scores would also indicate a dominance of the noncognitive components of speed processing and psychomotor skills abilities. Conversely, significant correlations between cognitive determinant scores and computerized simulated exercise test scores, low-low or high-high, would indicate a predominance of the cognitive components of psychomotor skills and speed processing.

If the noncognitive components of psychomotor skills and perceptual speed override the cognitive components of the same, then the cognitive determinant scores will not correlate with the computerized simulated exercise test scores, but grades in the preclinical technique courses may correlate. If the cognitive components of psychomotor skills and perceptual speed are more significant, there should be some correlation among the simulation score, the cognitive determinant scores, and the preclinical technique grades.
Method

With the approval of the university’s Institutional Review Board, twenty-nine entering first-year students from the Class of 2006 participated in the investigation. Predental grade point average (GPA), Biology/Chemistry/Physics grade point average (BCP), Dental Admission Test sub-test scores of Perceptual Ability Test (PAT), Academic Average (AA), and Total Science (TS), and grades from the first two preclinical restorative dentistry laboratory technique courses were made available to the investigators for all students participating in the investigation.

The apparatus used was a computerized dental treatment simulation device. The system consists of a pneumatically controlled manikin head connected to artificial jaws containing model teeth. The head is attached to a torso whose height can be adjusted. The system includes a swiveling delivery unit, a dental handpiece, a light, an overhead infrared camera with a monitor, and infrared sensors. Readings from the sensors on the manikin and handpiece are processed electronically to interpret spatial orientation and develop a three-dimensional image of the patient’s dentition. Accompanying software provides users with instructional feedback related to performance.

Prior to the students’ first experience using a dental handpiece, a ten-minute videotape detailing an ideal Class I amalgam preparation of a mandibular first molar tooth was shown to participating students individually. The videotape provided suggestions on how to use finger rests, what criterion points are used to score each preparation, and the properties of amalgam. The participants were given fifteen minutes to practice the use of the foot pedal, handpiece, and finger rests on an ivorine mandibular first molar tooth. Each participant was then given a new ivorine mandibular first molar tooth and twenty minutes to prepare an ideal Class I amalgam preparation. Because this exercise is a first-time experience, it was classified as requiring inconsistent information processing demands. On the monitor screen of the computer, the ideal amalgam Class I cavity preparation was shown at all times. Upon completion of the preparation, the computer scored each procedure, based on referenced criteria points. Student participation time required approximately fifty-five minutes.

The computerized simulated exercise test scores of all participants were correlated with AA sub-test scores of the DAT (Quantitative Reasoning Test, Reading Comprehension Test, and the Survey of Natural Science Test), PAT, TS, predental GPA, predental Biology/Chemistry/Physics grade point average (BCP), and grades from the first two preclinical laboratory technique courses (Lab 1 and Lab 2).

Results

This study used the correlational nature of inferential statistics to “predict” the computerized dental treatment simulator (SIM) score based on multiple independent variables. Thus, the SIM score was treated as an “outcome,” while multiple independent variables were used as predictors, allowing for them to be simultaneously included in a single model. The statistical method for analyzing the relationship between “outcome” and “predictors” is logical regression. The “outcome” variable for this analysis was SIM score. The control “predictor” variables were: BCP, GPA, AA, PAT, TS, Lab 1, and Lab 2.

The sample included twenty-nine dental students, all enrolled in the first year of the predoctoral program. The measures used in this investigation were all based on numerical scores. The results of the logical regression analysis are reported in Table 1. The results showed that there was a significant correlation (p<.05) between the SIM score and the AA, TS, and Lab 1 scores. This indicates that there is a positive correlation between the SIM score and these three scores. The SIM score did not correlate significantly with any of the other scores, including BCP, GPA, PAT, and Lab 2.

Discussion

Some dental educators believe that advanced technology simulation will dramatically affect health care education.14 This study evaluated the use of computerized simulated exercises to predict preclinical technique performance in dental school. Results showed a positive correlation between the simulator score and the AA (Academic Average) and TS (Total Science) sub-tests of the DAT, both considered determinants of general cognitive abilities. Based on this result, it would seem that the simulator may be a good measure of general cognitive ability and that the noncognitive components of perceptual speed and
psychomotor ability play a lesser role. Because the study involved first-time contact for the participants with the simulator and a handpiece, it may be that those with a higher cognitive ability have a greater capacity for following directions. Another explanation is that, for inconsistent information processing, the cognitive component is so predominant that the noncognitive is not measurable with this test.

The lack of correlation of the simulator scores with results on the PAT was unexpected. Because the PAT is considered to be essentially a measure of spatial and figural cognitive abilities, one would assume a positive correlation with simulator results. In analyzing the data relative to the student participants, we found that the average PAT score was 0.4 points higher than the average AA score and 1.3 points higher than the TS average. The PAT scores were higher in general and the range was smaller than that of the AA and TS scores. Because participation in the study was voluntary, it is conceivable that students electing to participate were those who felt most likely to perform at a high level based on PAT performance.

Preclinical technique course, Lab 1, involves waxing exercises for anterior and posterior teeth, amalgam and composite restorations of manufactured prepared teeth, and fabrication of one provisional restoration. In Lab 2, taught in the following semester, students are required to complete multiple complex preparations and restorations for a variety of materials, both intracoronal and extracoronal, including preparation and temporization for single unit crowns and two posterior three-unit bridges. The simulator exercise, to create a preparation for a Class I amalgam, was relatively uncomplicated and straightforward. The investigators believe that the exercises in Lab 1 were also relatively uncomplicated and most likely account for the positive correlation between simulator scores and grades in Lab 1. Procedures required for Lab 2 are much more complex and, as expected, did not correlate with performance on the simulator. Additionally, general skills obtained in Lab 1 may have positively affected performance in Lab 2, causing results to be better than expected from the simulation scores.

**Conclusion**

The purpose of this study was to determine if a computerized simulated exercise predicts students’ performance on preclinical laboratory exercises in dental school. Logically, the positive correlation of the simulator scores with the AA sub-test scores and the known correlation of AA sub-test scores with performance in the basic science courses might indicate that the simulator scores could be predictive of future performance in the basic science courses. However, results of this study were limited due to the technical sensitivity of the simulator unit and the relatively small sample size (n=29). From a practical viewpoint, the cost of a computerized simulation unit can be prohibitive, and its use should be maximized to include preclinical teaching, transition between preclinic and clinic, and as a variable in the admissions process. Further investigation is required for conclusive evidence regarding the predictive value of computerized simulation for dental school performance.
REFERENCES


