DEXTERITY TESTING AND RESIDENTS' SURGICAL PERFORMANCE*

BY *Thomas J. Kirby,* MD

INTRODUCTION

IN THE GENERAL POPULATION, SOME PERSONS AE INNATELY GIFTED OR TALENTED with their hands and some are innately clumsy. Most of us fall somewhere between the two extremes. Each of us has seen residents who have average manual skills develop into superb surgeons because of their superior motivation and superior intellect for learning surgical judgment. We have seen those with beautifully nimble fingers and hands who never develop the other talents necessary to become superior surgeons.

An occasional resident is found to be clumsy with his hands. He becomes a problem and a challenge to train to a level of competence and safety as a surgeon. If there were a test or a method of determining in advance whether a given individual is clumsy with his hands or whether he is manually adept, it would be helpful in determining which residents will need more intensive training in surgical technique before they begin the surgical rotation of their residency. Training in technique is helpful, but motivation and development of judgment will, of course, heavily influence a person's progress.

SUBJECTS

Two tests for manual dexterity were given to 123 applicants for a residency in ophthalmology at the Mayo Clinic as a part of their application interview and to seven volunteers from the current resident staff in ophthalmology. The volunteers had been accepted into the residency program before the testing was introduced into the interview sessions.

Ten residents who had taken the above test as applicants and the seven volunteers were graded by their teachers on surgical skills after they had finished the surgical rotation of their residency. The teachers were encouraged to avoid consideration of surgical judgment, personality, physician

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skills, and general work habits. They were asked to grade the ability to handle instruments, to cut, and to sew. The teachers did not know the results of the dexterity testing. The grades were given on the basis of one to ten with one being the least skilled and ten the most skilled.

TESTING TECHNIQUES

The O'Connor Finger Dexterity and Tweezer Dexterity Tests were selected because they were readily available and easy to administer. They appeared to have the capability for testing both manual dexterity and the ability to use fine instruments. Normal standards for the tests were determined years ago.

The equipment for the finger dexterity test consists of a board with 100 holes arranged in 10 rows of 10 holes each and spaced one-half inch apart. The holes are about 3/16 of an inch in diameter. Above the holes is a shallow well holding 300 metal pins; each pin is 1 inch long and about 1/16 of an inch in diameter. Each of the 100 holes in the board will accommodate three of the pins. The test requires that three pins be picked simultaneously, from the pile of pins with the fingers of one hand and placed into each of the 100

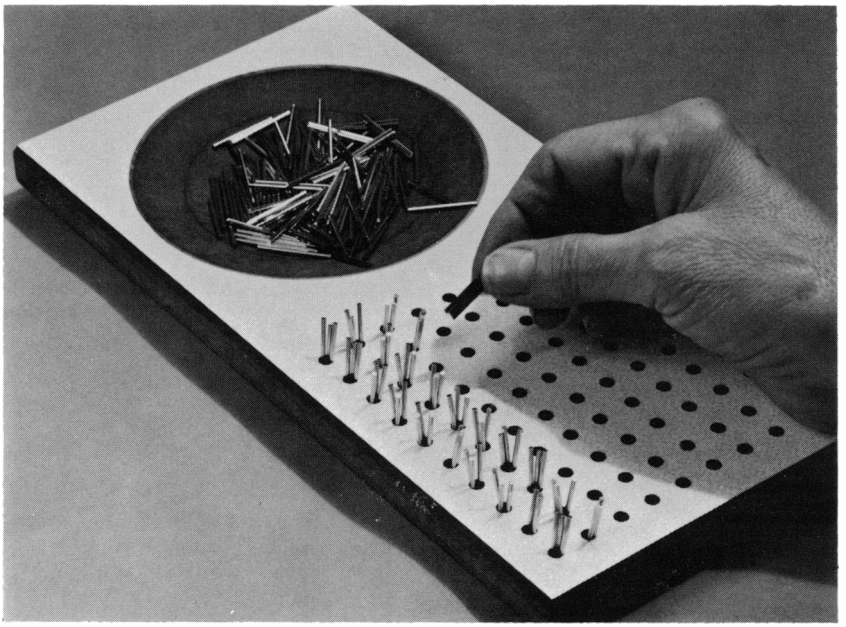

FIGURE 1
O'Connor Finger Dexterity Test.

holes. The time required, in seconds, to fill the 100 holes is the basis for the score. The fewer seconds required to fill the 100 holes the higher is the score (Fig 1).

The equipment for the tweezer dexterity test is basically the same except that each hole in a similar board is smaller and will accommodate only one pin at a time. The test requires that one pin be picked from the pile with a pointed tweezer and placed into each of the 100 holes. Again, the time required to fill the 100 holes is the basis for the score (Fig 2).

The literature describing the two tests is mostly old, dating back to the 1920s and 1930s. This literature and later publications on other forms of testing describe the strengths and limitations of dexterity testing.

The two tests used in this study have been used previously to select women for electrical instrument assembly,[1] electrical fixture and radio assembly,[2] watch assembly,[3] and four categories of electrical shop work of varying degrees of complexity,[4] and to predict the success of students in a course in high school shop mechanics.[5] A sample population of 475 men and 215 women from seven occupational groups ranging from unskilled laborers to professionals was tested to determine the reliability of the tests.[6]

Eighty-five per cent of the women who scored better than the median

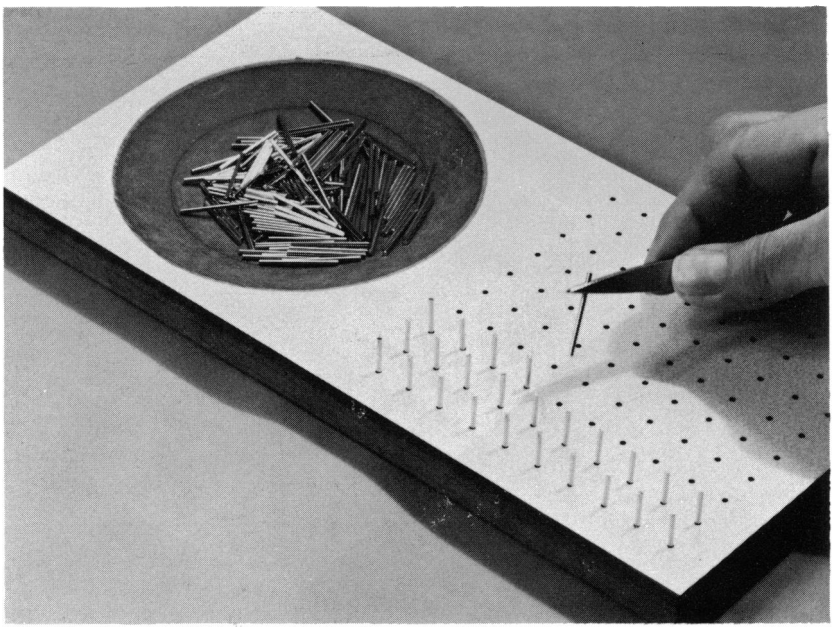

FIGURE 2
O'Connor Tweezer Dexterity Test.

(50th percentile) on the finger test were successful in electrical instrument assembly.[1] Data on the finger test revealed a reliability coefficient of 0.93 for men and 0.90 for women. Correlation studies suggested, but did not prove, a high reliability for the tweezer test.[6]

Hand and arm coordination were not predicted by the finger dexterity test, but it was reliable for assembly of small and fine parts. In the same study, the Hand Precision Test picked careful but slower workers (quality versus quantity), and The Keystone Visual Safety Test also picked quality-producing but usually slower workers.[2] Watch factory workers scored higher on the finger and tweezer tests than did general factory workers; the two tests selected competent applicants for watch factory work with higher degree of success than did an interview alone.[3] The correlation between job proficiency and the two dexterity tests was significant for four categories of electrical shop workers. The test scores were more selective and consistent for success on the job than were age, schooling, previous experience, and marital status.[4] A study of the validity of seven manual dexterity tests in predicting success in high school shop mechanics ranked the O'Connor Finger Dexterity Test as sixth. No explanation could be offered for the low ranking since the students were chosen at random from the various classrooms. In the same study, arm-and-hand dexterity was best predicted by the Minnesota Rate of Manipulation Test and the Stromberg Dexterity Test, two-hand coordination was best predicted by the Purdue Pegboard, and eye-hand coordination was best predicted by the Crawford Small Parts Dexterity Test.[5]

RESULTS

The scores on the dexterity test and the teachers' grades for the seven volunteers were compared with those of the 10 persons who had taken the tests as applicants for residency. There was no significant statistical difference between the two groups, and so the seven volunteers were left in the study.

The performance of the 17 residents on the finger dexterity test was slightly higher than that of the general population. The median raw score for the 17 residents was 262.5; the median raw score of the norms was 280. The raw scores of 13 of the 17 residents were higher than the medium of the norms. In the general population, one would expect only eight or nine to have median scores equal to or better than the norms. Use of a chi-square test of the hypothesis that the residents came from the same population as the norms yielded $\chi^2_1 = 4.76$ with a P value of 0.03, which is of slight statistical significance, and indicates that it is likely that the residents came from a population with higher finger dexterity ability. The residents' raw

RAW SCORES

		FINGER DEXTERITY		TWEEZER DEXTERITY	
		Median	Range	Median	Range
NORMALS	Males	280	598-183	360	615-255
	Females	244	462-166	342	544-249
MAYO RESIDENTS		262.5	316-192	346	555-270

$X^2_1 = 4.76$

$p = .03$

FIGURE 3
Median raw scores of residents on both dexterity tests compared with the norms.

scores for the tweezer dexterity test were not significantly different from the norms (Fig 3).

The percentile scores of the residents on each of the dexterity tests were plotted on a graph against the mean score given each resident by the teachers (Figs 4 and 5) and against each other (Fig 6). The graphs reveal no pattern or curve of correlation between the teachers' grading and either of the dexterity tests or between the two dexterity tests themselves.

Analysis using Spearman's rank correlation yielded a correlation of 0.29 between the teachers' grading and the finger test, 0.22 between the

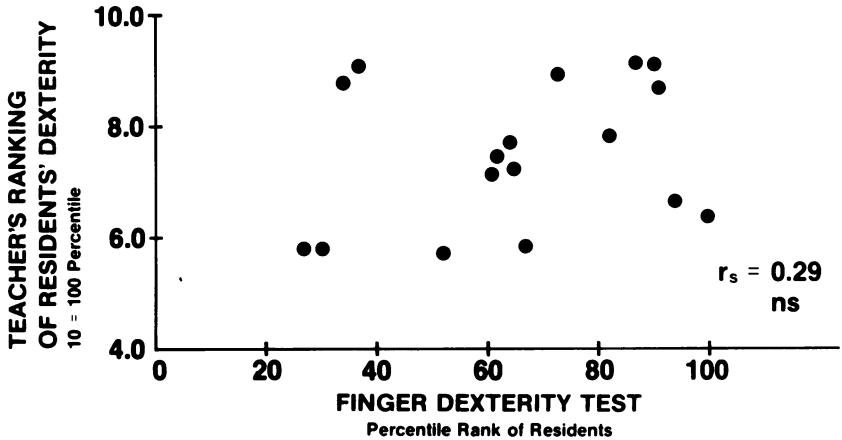

FIGURE 4
Percentile rank of residents on the finger dexterity test plotted against the grades given by the teachers.

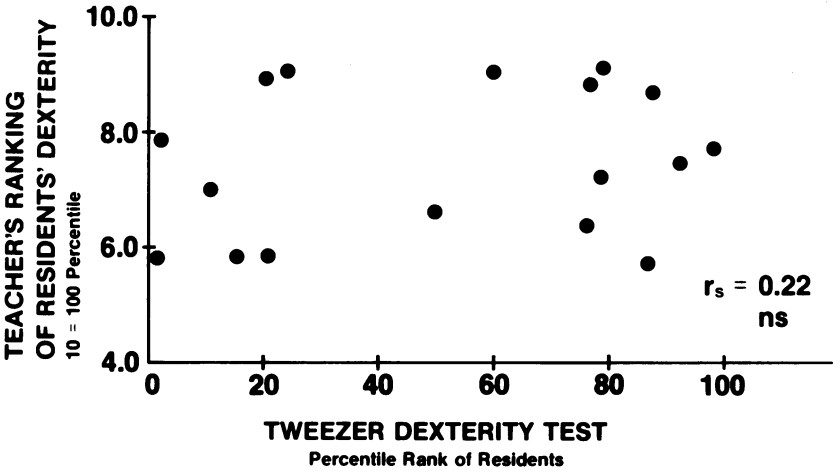

FIGURE 5
Percentile rank of the residents on the tweezer dexterity test plotted against the grades given by the teachers.

teachers' grading and the tweezer test, and 0.16 between the two tests. The three resultant coefficients were not statistically significant.

The teachers' grading of the residents was plotted on a graph to determine if there was bias. The graph revealed no individual bias or discrepancy in grading the residents.

DISCUSSION

The two dexterity tests seem to have failed statistically, in this study, to adequately predict the 17 residents' ability to handle instruments, to cut, and to sew. The description and instructions for giving the tests suggested that they would be helpful.

However, it is interesting to report that the one resident with the lowest scores on each of the dexterity tests was graded as number 15 of the 17 by the teachers. The resident graded as number one by the teachers had a rank of five on each dexterity test. Later during their residency, three residents were chosen by their teachers to become Chief Resident Associates. The three had ranked 7, 5, and 3 on the finger test. On the tweezer test, the three had ranked 12, 5, and 3, respectively. The teachers selecting the Chief Resident Associates did not know the scores of the dexterity tests. Obviously, and as expected, many qualities, including proven surgical dexterity, were considered for appointment to the position of Chief Resident Associate.

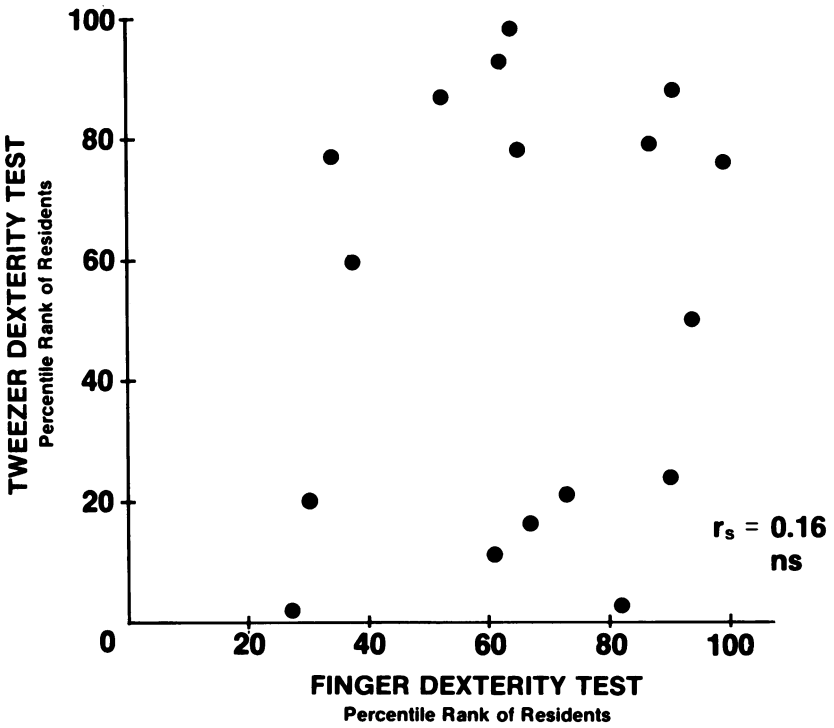

FIGURE 6
Percentile rank of the residents on the finger dexterity test plotted against the percentile rank of the residents on the tweezer dexterity test.

Although there is no significant statistical correlation between the two tests and early surgical performance for the 17 residents, these or other tests could possibly be of practical value in identifying innately clumsy residents who could benefit from more intensive training in surgical technique before they reached the surgical rotation of their residency.

Early identification of those who may need more intensive teaching and prodding to develop surgical judgment is more intangible, complicated, and dependent on astute evaluation of each resident by his teachers.

Should we have picked a different dexterity test or should we use one at all?

Functions measured by commercially available motor tests such as the ones used in this study are often simple. These tests serve best as a part of a battery of selection tests rather than single predictors. These tests are better for predicting performance on routine assembling and machine-operating jobs. As jobs become less repetitive, perceptual and intellectual

factors play a more important part. Spatial aptitude or the ability to visualize and manipulate objects in space has become a part of the better tests for general intelligence.[7]

The Perceptual Motor Ability Test given to predental students is concerned with spatial aptitudes, involving both two-dimensional and three-dimensional perception. It is a pencil and paper test. How accurately the test could predict surgical performance by eye residents is unknown.

If a test is to be used, should it be a simple, quickly administered screening test or a complex battery of tests? The practicality of time available for interviews suggests that it should be a short, simple test.

Over a period of 21 years before the present study, four residents had been found to have faulty stereopsis after being accepted into the residency program. These four were grouped with a contemporary resident, a resident 3 months ahead of them, and a resident 3 months behind them on the surgical rotation. A few extra random residents were thrown into the group. The individuals were mixed haphazardly in an attempt to camouflage the intent of the study from the teachers. The teachers were asked to grade the resident's manual surgical skills as well as they could remember them. The resident with faulty stereopsis was generally graded lower than his contemporary or near contemporaries. However, the number of residents compared and the number of teachers who were senior enough to have taught the residents were too small to allow a reliable statistical comparison.

These four former residents are now considered competent, safe surgeons for general ophthalmic surgery. We do not know whether, or how well, they have performed with microsurgery of the anterior segment, intraocular lenses, or the complexities of vitreoretinal surgery.

Those who have trained residents with faulty stereopsis usually feel that more effort goes into the training process by both the teacher and the resident.

It seems safe to say that surgical skill is, to some degree, a learned skill and several factors influence the development of that skill.

The following and other factors may influence a resident's progress in surgical performance:

1. Normal or above-average manual dexterity.
2. Judgment (special intelligence): an innate ability to think and plan, which is enhanced by study, problem-solving ability, absorption of teaching, and learning from observation.
3. Previous experience: hobbies that have demanded the use of small hand tools and the development of mechanical and special aptitudes, and experience in other fields of surgery.

4. Training: didactic and direct guidance in a surgical technique laboratory.

5. Motivation to excel: study to develop judgment and the skills of learning from teachers and from obervation, repetitive practice of surgical technique, and recognition of one's weaknesses and frequent return to the laboratory to correct those weaknesses.

6. Stereopsis and normal visual acuity.

7. Visual-spatial aptitude: the ability to plan and visualize a project in three dimensions (stereoscopic mental imagery).

SUMMARY

1. With some exceptions, those who choose ophthalmology as a career may approximate the general population in innate manual dexterity.

2. Many factors other than manual dexterity influence the development of surgical skills by residents.

3. If dexterity testing is to be used, the addition or inclusion of tests for spatial aptitudes may be more helpful than simple dexterity tests alone. The predictive value of such tests for surgical performance would need vertification.

4. The development of a special test directly related to handling surgical instruments, to cutting, and to sewing (the criteria) may be more practical than the ones used in this study.

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DISCUSSION

DR BRUCE E. SPIVEY. I am extremely pleased to have the opportunity to comment on this important paper. Doctor Kirby is to be congratulated for the first step in the

study of an area that has long suffered benign neglect in ophthalmology.

I would like to begin with some general comments. Is there evidence that some ophthalmologists are not sufficiently competent because of poor manual dexterity? Is manual dexterity a critical component of ophthalmologic competence? Obviously, we would all prefer the surgeon with "good hands" but what is the relationship between the surgical outcome and complications of those with "good hands" and those who would not be rated so high either by dexterity testing or by observers. I think we can all agree that at the minimum the evaluation of manual dexterity should be used for new residents to determine those who may need special or extra training and remediation before they go into the operating room. This may be tested by more practical means such as practice surgery on animals prior to direct patient experience. It may be inappropriate to consider the use of manual dexterity as screening for selection of residents particularly because of the wide opportunities ophthalmologists have in the nonsurgical aspects of our specialty. The recent manpower survey would indicate that 93% of ophthalmologists' practice is nonsurgical.

How do we identify a valid and reliable criterion measure for manual dexterity or "good hands?" By criterion measure we mean some way to test or assess the target performance we're interested in—in this case it might be a direct rating of the surgeon's smoothness or accuracy in a particular situation (similar to judging various components of a diver's or gymnast's execution of a task with a given degree of difficulty). Or it might be an indirect measure such as rate of surgical complications. Surgical complications are only one factor; this must be controlled for complexity of the procedure and the patient problem. Certainly, operating time is another measure, but some exquisite surgeons are slow, yet careful. I do believe it would be possible to videotape some standard procedures and then develop criteria or standards for excellent, satisfactory and poor performance. With these tapes and standards, raters could be trained to be reliable and residents and others could be observed and rated. The accuracy of the predictive or screening test is highly dependent on the adequacy of the criterion measure. It is the only means of determining the relative effectiveness of the trial predictors.

In the two tests that Doctor Kirby employed, there is inconsistency in the results and, therefore, there is no reason to pick one test over the other; in fact, there is no reason to use the tests at all since the scatter diagrams show no predictive value for either test and no correlation between the two tests. However, simply on the face validity of the two tests the tweezer dexterity would appear to be slightly more valid than the O'Connor finger dexterity.

The way the faculty rated the residents the criterion measure has not been described specifically enough to ascertain its validity or reliability. Were any standards or criteria anchored to the 1 to 10 rating scale? We can see that only a restricted range of the scale was used, ie, 6 to 9. This restricted variance of the criterion measure would in itself reduce the correlation with the screening tests. Doctor Kirby told us that the voters were instructed to avoid bias from non-surgical factors (eg, judgment), but we do not know much else about the criterion measure. Since we are judging the value of the screening tests in relation to this criterion, it is

important that the criterion measure be trustworthy and useful. At this point we cannot be clear whether the screening tests are not good, or the criterion measures invalid, or both.

There are several possibilities for measuring competence, one or more of which could be implemented, depending on interest, available time and other resources. If we believe manual dexterity is of sufficient importance, we must be willing to do something in a formal way about assessing and improving surgical skills, assuming that our already accepted residents are not so clumsy as to be unable to rise above minimal competence. One option would be to develop measures to assess skill ranging from refining our rating sheets up to videotaping the procedures and training the raters, if resources and energy for this is available. This would improve our criterion measure against which we could evaluate the screening or predictive tests. Another option is to evaluate existing manual dexterity tests, looking for those with greater face validity or those that predict skills closer to those required in eye surgery.

As a third option, we should develop our own tests with greater face validity such as cutting to a predetermined depth in some synthetic material, or carrying out spatial manipulations under a microscope. Historically, dentistry has used chalk carving as a measure of perceptual motor ability. The chalk carving test measured manual dexterity as well as the ability to follow directions and to visualize in three dimensions. The test had several disadvantages, not the least of which was the cost and difficulty involved in administering it, although the test did have modest predictive value. Because of the difficulties, a paper and pencil test was developed to measure factors related to visual discrimination and spatial perception. At least in dentistry, perception is probably a major underlying factor in the ability to perform such motor tasks as cavity preparation. In general, the test predicted grades in the clinical technical courses as well as the chalk carving test, but the correlations were never very substantial (on the order of 0.25 overall). It is of interest to note, however, that poor performance on the perceptual motor ability test *did* correlate well with those students who withdrew from dental school because of insurmountable difficulty in their technique courses.

Doctor Kirby has taken the first step in a most important and presently neglected area.

Dr Robert Machemer. I have always been interested in finding out if there are any tests that might allow us to evaluate a resident or fellow for manual dexterity, as we are in a surgical specialty in which microsurgery is emphasized. In discussing this with people of Storz Instrument Company who try to hire young men with manual dexterity, I found a helpful hint. They said that it was most important to them to determine the hobbies of the applicants. They request that prospective employees bring with them whatever evidence of manual dexterity they have, such as little model cars or hand made jewelry. The second most valid evidence for dexterity for them was the performance in a space-relation test (Psychological Corporation, New York; Differential Aptitude Test [Space Relations]). In this test you mentally have to fold a pattern to form a box and compare it to four different shapes. A multitude of

such patterns is provided with increasing difficulty. In evaluating a resident or fellow for dexterity, we are dealing with something that is very difficult to judge. Most residents and fellows learn to handle surgical instruments by the simple fact of repetition and need not be unusually dexterous. However, given the choice, we would like to find and select the applicant with the most outstanding manual capabilities.

There is something else we would like to know at the time of selection of residents and fellows, namely their capability of handling extraordinary situations. I was very impressed by a test given by the plastic surgeon Blascovitch of Hungaria. Whenever someone applied he would give him five wooden matches and tell him to pick up these matches in such a way that he would end up having one of the matches between each opposing fingers. I personally think this test gives a lot of information, not only about dexterity, but more about how to handle a problem.

Dr Thomas D. Duane. Doctor Kirby, I think this is a great paper. There are two aspects that I want to discuss. One is selection and the other is evaluation. As far as selection is concerned, at our institution Doctor William Tasman is the head of our selection committee and he has a pile of toothpicks that he asks the candidates to pick up like Doctor Machemer described. While he or she is doing this we try to bug them with controversial questions and ask them what they think of the Bakke Judicial decision or of President Carter or anything else. I have not been very impressed that we really differentiated anybody with this test. It does sort of test their cool under stress, but I don't know if there's any great correlation between that and their future performance. In fact, I don't think we have any good way of selecting residents. The more I watch it the more convinced I am that it's a very inexact science and when I talk to the heads of admission Committees at the medical schools and colleges they say pretty much the same thing. Maybe it's just as well we don't have too much of a mechanical way of choosing people. I also liked this paper because, as Doctors Kearns, Spencer and Richards who are at this meeting and I know, as members of the Residency Review Committee, from attempting to accredit residencies around the country if there is anything conspicuously lacking in residencies it is that evaluation is almost nonexistent. In other words, we usually do not tell the residents what they are expected to do and what they are expected to know and we don't then test them and the few places that do hardly ever share the results with the resident. When it comes to fellowships, except for the fellowship that was written into a program by Doctor Friendly of Washington, I don't know anybody that evaluates fellows. In fact, very frequently I am asked about some fellow that had been in our institution 3 to 4 years previously and if I cannot find his immediate mentor, I have no way of knowing whether he was competent. Nobody is really evaluated in our hospital and I don't think this is fair. It isn't fair to the candidate, it isn't fair to the public and it isn't fair to our specialty and so I salute Doctor Kirby for making us think of something that we ought to do and that is to evaluate the product that we are trying to train.

Dr J. Reimer Wolter. Doctor Kirby is asking for a manual dexterity test that

resembles the actual functions of an eye surgeon in the operating room. I have developed such a test and found it very useful. In this test a spherical styrofoam shell of the kind commonly used for packing and resembling an ocular conformer is cut in half with a razor blade. The examinee is asked to sew the two halves back together again—using a silk suture and a needle holder. He is asked to suture those two halves back together again from the outside without perforating the inside, and I have tested this only very slightly and found it very interesting because it gives depth feeling as the styrofoam is very light. One has to kind of follow the needle with a hand movement and it seems to work very well. This does not interest people who have never heard about eye surgery such as my children for example.

Dr Daniel M. Taylor. Dr Kirby is to be congratulated for his initial efforts in a relatively unexplored area. Ophthalmic surgery represents only 7% of the entire field of ophthalmology, but it is none-the-less that treatment area which deals most directly with serious blinding eye disease. We should therefore, have more than a casual interest in selecting those candidates who are primarily interested in ophthalmic surgery. It would seem wise to screen out those candidates who exhibit poor surgical dexterity or eye-hand coordination and those who appear to be grossly unsuitable by personality or temperament. Surgical judgment would, of course, be extremely difficult to evaluate. For a number of years I have been involved with teaching corneal transplantation surgery at the Fellowship level. The test that I find to be most effective in the selection of future corneal surgeons is to invite all qualified candidates (post-residency level) to spend time with me in the operating room. In addition to allowing them to assist, I usually permit them to do some phase of the operation. With this technique of direct testing and observation under fire I can usually determine which candidates actually do possess the greatest dexterity or natural surgical ability and how they react under stress. This has worked very well for us over the past four years and I believe exceeds any other method of evaluation including the non-clinical dexterity tests discussed today.

Dr Richard Troutman. Almost a century ago, a great English surgeon stated that "success is attention to detail." I think in ophthalmology more than any other specialty, the use of the surgical microscope, at least in my hands and those of the residents I have trained, has increased our surgical dexterity and improved our surgical results by providing the new dimension of magnification not available before. Some of you who, with me, were examined for the Boards some years ago will recall the cat eye we were required to operate on during the examination. Those of you who were on the examining Board at that time probably could attest to the fact that the examinees had to keep their cool, as well as the residents supplying the cat eyes. As we progress more and more into the new ophthalmic surgery, I forsee that we will necessarily be less and less dependent on manual dexterity. New instrumentation in our specialty will be increasingly cybernetically controlled in future ophthalmic surgery. We have passed the point where manual dexterity alone can perform what we see microscopically needs to be done. Here we have the challenge for the future.

DR THOMAS J. KIRBY. I want to thank all of the discussors of my paper, and particularly Doctor Spivey, who was kind enough to bring to me a copy of his discussion. First, Doctor Spivey is right about the grading of the residents' performance. I instructed our teachers to grade on the basis of one to ten and to grade only on their ability to cut, sew and handle instruments. The fact that the teachers graded none of the residents below six did, as Doctor Spivey points out, restrict the range of grades and reduced the chance of statistical correlation with the screening tests. Therefore, the grading in this study does not comply exactly with the modern PhD in Education criteria for proper grading. However, I would like to take some personal credit for the fact that none of our residents scored below six because for the past 15 years each resident has spent a minimum of 12 hours with me in my surgical technique laboratory on a one to one teaching basis. In addition, each spends 18-24 hours in the lab practicing over and over again what I have taught him during our one to one sessions. I agree that if we are to use dexterity testing to screen applicants and if acceptance into a residency is dependent upon that testing, then we should be sure that the tests meet the criterion for measuring surgical performance according to the guidelines approved by our PhD's in Education. It would take several years to develop a valid and reliable test, to establish normals for the test and to train the graders. I might add that no applicants have been rejected on the basis of their scores on the tests used in this study. The study has been useful as a pilot to gain information for future decisions on training the young ophthalmic surgeon.

Doctor Machemer's mention of an applicant's hobbies as an indicator of potential surgical ability is certainly appropriate. We also inquire about hobbies during interviews and certainly the over and over again repetition of practice is helpful to both the innately dexterous and those less endowed.

I thank Doctor Duane for his kind remarks about my paper and agree that the selection of residents is an inexact science. I know what is going through his mind. As Chairman of the Resident Selection Committee at the Mayo Clinic, I can agree that selection is a most arduous and worrisome job and chore. We do test our residents regularly. They are given oral examinations every two months on the didactic program, they are graded quarterly on all aspects of their work, a grade is given in surgical technique laboratory anatomy and in pathology and, of course, they all take the OKAP exams.

Doctor Wolter, I think your test of suturing a halved styrofoam shell is wonderful. It does show if an applicant can handle surgical instruments, suture material and can sew.

I can appreciate Doctor Taylor's approach to selecting fellows for his corneal service. The ability to react and function under pressure can be a good indicator.

I've enjoyed giving this paper, presenting it partly with tongue in cheeck, but also with seriousness. The idea of testing innate dexterity should not be discarded. Selection of residents is most important; to teach them is equally or more important. Teaching programs have a high responsibility for both selection and training.