Palpatory Diagnosis Training on the Virtual Haptic Back: Performance Improvement and User Evaluations

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The Virtual Haptic Back is a teaching aid for osteopathic medical students learning palpatory diagnosis. Students trained on the Virtual Haptic Back improved their ability to resolve small differences in simulated tissue texture and reported that the practice sessions were helpful in developing their palpatory skill in the osteopathic manipulative medicine teaching laboratory.

ABSTRACT

Context: Learning palpatory diagnosis is a challenge for many osteopathic medical students. The Virtual Haptic Back (VHB) is an aid in teaching and learning palpatory skills. It simulates the contours of human backs and and the compliances of their surfaces, and allows these to be felt through the haptic interfaces. Regions of abnormal tissue texture are simulated by altered surface compliance.

Objective: To examine the effect of practice with the VHB by osteopathic medical students on their palpatory performance and to record the subjective impressions of the students as to the potential value of the VHB in learning palpatory diagnosis.

Methods: Twenty-one first-year osteopathic medical students at Ohio University College of Osteopathic Medicine in Athens took performance tests on the VHB before and after a series of eight 15-minute practice sessions, which occurred over 2-week periods from September, 2005, through January, 2006. The tests measured their accuracy and speed in locating regions of abnormal compliance in the back. The location of abnormal regions was varied randomly among 12 sites, and five different levels of difficulty were tested. At the easier levels the compliance of the abnormal region was very different from remainder of the back; at the harder levels the differences were very subtle. Performance of the students during the practice sessions was also monitored. After completing the practice sessions and performance tests, students filled out a questionnaire indicating their impressions of the potential value of the VHB as learning aid.

Results: As a group students improved in accuracy and speed following the practice

sessions, compared with the initial performance test. Subjects improved from being able

to detect only a 40% difference in compliance to being able to detect an 11% difference.

These results, plus the performance profiles during the practice sessions, revealed that the

greatest improvements occurred at the difficulty levels near the apparent detection limit

of compliance differences. Survey responses indicated that students thought the VHB

experience was helpful to them in developing their palpatory skills.

Conclusion: The Virtual Haptic Back has potential as an effective aid to osteopathic

medical students in learning palpatory diagnosis.

INTRODUCTION

The Virtual Haptic Back (VHB) is being developed as an aid to the teaching and learning

of palpatory diagnosis. The term, haptics, refers to the human sense of touch. Palpation of

the human back is used diagnostically by osteopathic physicians and other clinicians to

detect musculoskeletal abnormalities collectively referred to as somatic dysfunction.[1].

One characteristic of these abnormalities is altered tissue texture, which reflects altered

tension in underlying muscles and connective tissues. A major component of tissue

texture is tissue compliance, (tissue displacement per unit of applied force). The

reciprocal of compliance is elastance, more commonly known as stiffness (force

generated per unit of displacement).

The VHB simulates the contour and compliance properties of human backs. These properties are palpated simultaneously with two digits, fingers or thumbs, through two haptic interfaces (PHANTOM® 3.0 from SensAble Technologies, Woburn, MA). The digits, from either the same or opposite hands, are placed in thimble-like devices at the end of movable mechanical arms of the haptic interfaces (*Figure 1*). Small electric motors built into the arms provide resistance to movement of the fingers that simulates the palpatory properties of the back.
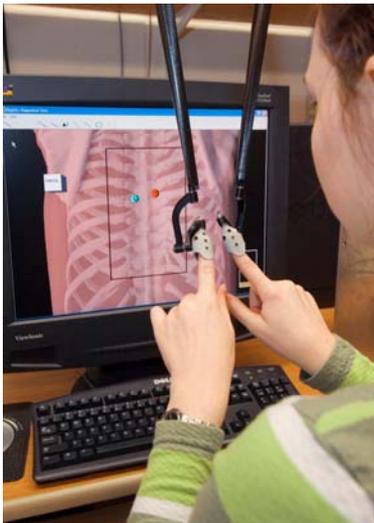

Figure 1. Osteopathic medical student using the Virtual Haptic Back.

The Virtual Haptic Back simulation allows students to practice detecting and localizing compliance patterns that reflect clinically observed abnormalities. The location of the abnormalities on the back is varied randomly and the difficulty level of the task can be varied by making the abnormalities obvious or very subtle. In this study we sought to determine if training on the VHB would increase the ability of users to detect small differences in compliance between adjacent areas on the back.

The smallest difference that can be detected by any sensory system of the body is called the "just-noticeable difference." When this difference is expressed as a fractional change, it is known as the Weber fraction.[2] The Weber fraction is sometimes expressed as a percent. For instance a Weber fraction of 0.11 indicates that one can detect an 11% difference. In a study of compliance detection Dhruv and Tendick[3], using a PHANTOM 1.5 haptic interface, found Weber fractions in the range of 0.14 to 0.25 (14% to 25%) for a simple mechanical task consisting of pressing a finger against a resistance that behaved as a linear spring.

In a similar study, DeGersem,[4] also using the PHANTOM 1.5, reported Weber fractions between 0.08 and 0.12 achieved by 6 subjects studied. The range of compliance values used by DeGersem[4] included the range of compliance values previously measured over paraspinal muscles (0.8 mm/N to 1.2 mm/N in the thoracic region and up to 1.6 mm/N in the lumbar region).[5]

The Virtual Haptic Back (VHB) described in the current study presents students with a more complex task than those studied by Dhruv and Tendick[3] and DeGersem.[4] The current study shows that, through practice, VHB subjects were able to achieve the same level of compliance discrimination that had been achieved by subjects in the previously described studies.[3,4] Subjects in the current study also reported that the VHB experience was helpful to them in the development of their palpatory skills in the osteopathic manipulative medicine teaching laboratory.

The Virtual Haptic Back

The contour and compliance properties of the human back are simulated with The Virtual Haptic Back (VHB). The contour was modified from the Visible Female data set.[8] The compliance values were initially chosen to match the subjective feel of a real back, as determined by osteopathic specialists in neuromusculoskeletal medicine. They were spot checked against compliance measurements made on actual human backs using a PHANTOM® Premium 3.0 (SensAble Technologies Inc, Woburn, Mass), which was equipped with a probe 2 cm in diameter and used to assess displacement as a function of force applied in graded steps up to 6 N.

Users of the VHB can feel the virtual back with two fingers from the same or opposite hands placed into the thimble-like receptacles at the ends of the mechanical arms of the haptic interfaces (*Figure 1*). Small electric motors built into the arms provide resistance to movement of the fingers that simulates the surface properties of the haptic back. The simulation allows users to practice detecting and localizing compliance patterns that reflect clinically observed abnormalities.

Approximately 15 cm behind the haptic back is a full-sized visual image of the back displayed on a 23-in flat screen monitor (*Figure 2*).

Figure 2. Graphic image of Virtual Haptic Back during the pre- and posttests. Dots marked "L" and "R" indicate the position of the two palpating digits. The central rectangle indicates the region where abnormal compliance can be found. The trial number and difficulty level appear in the upper left. Total time elapsed in the test appears at left, and the time remaining in the present trial appears at right. The box in the lower right is a force indicator, which rises to the level of the horizontal line before the system verbally warns the subject against using too much force.

Two dots on the screen, labeled L and R, indicate visually where the user's fingers are with respect to the haptic back. In this way, the user is able to bring his or her fingers directly to the center of the haptic back in order to begin palpation.

In the VHB model used in the current study, the back was programmed in C++ using the OpenHaptics software toolkit, GHOST SDK (SensAble Technologies Inc, Woburn, Mass), and OpenGL, version 1.5.1 (SGI, Sunnyvale, Calif) for graphics. It was programmed to have a uniform compliance except for a small 2.5 cm by 3.0 cm area of simulated somatic dysfunction (*Figure 3*). The entire region of testing was a rectangle 13.5 cm wide and 22 cm high, superimposed on the graphics image of the back and encompassing thoracic segments T5 through T10.
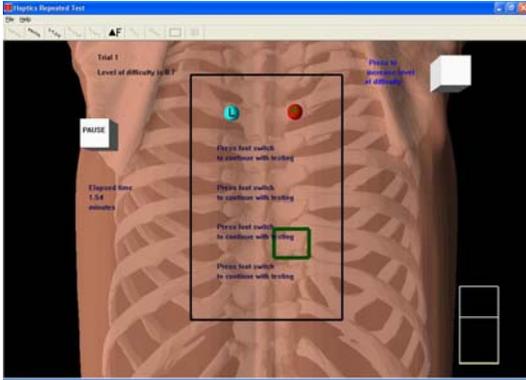
Figure 3. Appearance of the Virtual Haptic Back screen following an incorrect answer provided by a student during practice sessions. The small green box indicates the actual location of the abnormal area over the right transverse process of thoracic segment T9. By touching the upper left box with a L or R finger dot, the user can pause the program; by touching the upper right box, the user can alter the difficulty level of the next trial. These boxes can be accessed at any time during the practice sessions. (Skeletal elements were taken from the Visible Female data set.[8])

The compliance of the abnormal region, which ranged from 0.97 mm/N to 2.45 mm/N in the current study, was made to blend smoothly into the compliance of the surrounding areas (2.52 mm/N) with a hyperbolic tangent function:

$$f(x) = 1/2\{\tanh[a(x-b)+c] - \tanh[a(x-b)-c]\}$$

where a is the distance over which compliance transition occurs; b is the distance between the center of the abnormal area and a reference point, such as the body midline; and c is the width of the abnormal area. This adjustment prevents a sharp demarcation separating the abnormal from the normal regions.

In discriminating between two different linear compliances in the VHB, applying greater force causes increasingly greater differences in displacement. This initially leads users to press harder if they are having difficulty detecting the abnormal region. However, sustained application of force levels over 6 N can cause the electric motors of the haptic

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interfaces to overheat, which in turn can cause the program to shut down. The application of high forces is also clinically inappropriate because of potential patient discomfort and because palpatory information from superficial soft tissues can be lost by applying too much force. Higher force levels are utilized in palpation of the position of boney landmarks, such as tranverse process of vertebrae. To discourage users from pushing too hard, we added the following components to the VHB:

- When users apply unacceptably high forces, automated voice feedback warns them not to press so hard.
- A visual gauge in the lower right of the screen monitors user force levels, enabling users to see when they are approaching unacceptably high force levels (visible in *Figure 1* and *Figure 2*).
- Most importantly, the programmed compliance difference between the abnormal area and the surrounding areas is multiplied by a second hyperbolic tangent function, which makes the difference gradually disappear with increasing displacements between 8 mm and 16 mm.

Thus the compliance differences were maximum in a desirable range of force application, about 3 N in the normal regions (Figure 4). Based on preliminary measurements, this force level falls within the range of forces typically exerted by experts in clinical palpatory diagnosis during palpation of superficial soft tissues.[9]
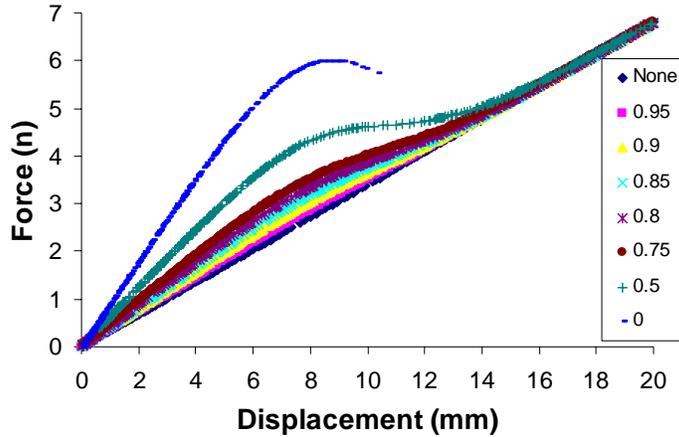
Figure 4. Relationship between the subjects' applied force and displacement at different difficulty levels (N=21). The straight line indicates background elastance (compliance^{-1}). Increasing deviations from this background elastance make the task progressively easier. The deviations disappear at high displacements produced by application of high forces.

Methods

Subjects (N = 21) were first-year osteopathic medical student volunteers from the Ohio University College of Osteopathic Medicine (OU-COM) in Athens. All subjects were within the first 5 months of their palpatory training. The proposal for this research was submitted to the Ohio University institutional review board and was judged to be exempt from review.

@subhead:Preliminary Session and Pretest

During their first session in the laboratory, subjects were given an opportunity to familiarize themselves with the haptic interfaces, practicing 10 to 15 minutes to identify regions of abnormal compliance. During this familiarization session, a transparency function was activated (*Figure 3*), permitting the user to see the skeletal elements beneath the skin for reference.

Following this preliminary phase, subjects took a test with an opaque virtual back (*Figure 2*), in which they had to locate the regions of abnormal compliance presented in successive trials. The location of the abnormal region of the haptic back varied randomly among trials. The abnormalities could be on either the left or right side and at any 1 of 6 thoracic levels, T5 through T10 (*Figure 5*). Subjects typically moved their fingers along the haptic back searching for regional differences in tissue compliance, later returning to regions they suspected might be abnormal. When they had decided which area was abnormal, they pressed a foot switch while holding a finger on the abnormal area. The system provided immediate verbal feedback as to whether the choice was correct or not.
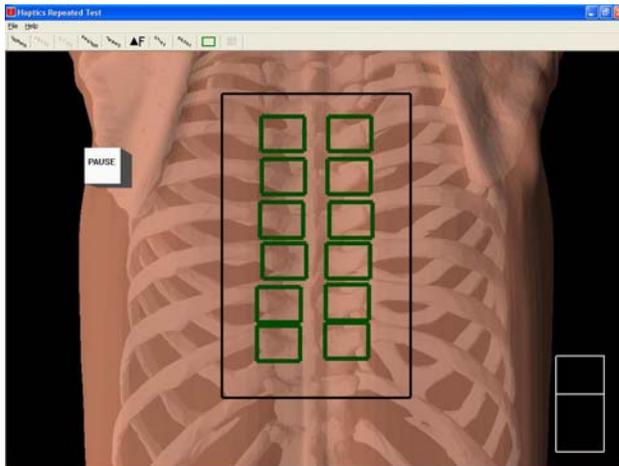
Figure 5. The regions of abnormalities in The Haptic Back were on either side over the transverse processes of thoracic spinal segments T5 through T10.

Five levels of difficulty, corresponding to various compliance differences, were presented in the pretest. Difficulty levels of 0.5, 0.7, 0.8, 0.9, and 0.95, were used, corresponding to Weber fractions ranging from 40.1 to 2.8. (Table 1) The pretest began with the easiest level (0.5) and progressed incrementally to the most difficult level (0.95) There were two trials at each difficulty level. Students were required to complete each trial within 1

minute (time remaining was visible on the screen). Midway through the test, the program

paused, giving the subject an opportunity to take his or her fingers out of the apparatus

and rest.

Difficulty level	Compliance	Weber fraction
	mm/N	%
0.00	0.97	61.5
0.25	1.19	52.8
0.50	1.51	40.1
0.70	1.98	21.4
0.75	2.14	15.1
0.80	2.25	10.7
0.85	2.29	9.1
0.90	2.35	6.7
0.95	2.45	2.8
background	2.52	

Table 1. Compliance values and corresponding Weber fractions, expressed as %, for each

difficulty level. Background compliance was 2.52 mm/N.

Practice Sessions

Immediately following the pretest, subjects carried out the first of eight practice sessions

to be completed in two weeks. Subjects were permitted to complete the practice sessions

at their own convenience but were allowed no more than one session per day. Individual

trials during the sessions were not timed, but each practice session was limited to 15

minutes.

Nine levels of difficulty were available in each practice session, compared with five

levels used in testing (Table 1). Although the setting at the start of each session of the

program was at the easiest level (greatest compliance difference), subjects could then pick any level of difficulty at which to work. Most started with the easier levels in the earlier sessions and progressed to the harder levels in the later sessions.

In the practice sessions, when subjects incorrectly identified an abnormality in tissue compliance, a recorded voice told them of their error and displayed a box around the correct area on the screen with the transparency function turned on (*Figure 3*). Subjects could then feel the abnormality before going on to the next trial. Subjects could also pause the practice session at any time to rest.

Posttest and Survey

To evaluate students for performance improvements, the pretest previously described was readministered as a posttest at the end of the 2-week practice sequence. After completion of the posttest, students were asked to complete a brief survey (*Figure X*) regarding the VHB and its value as a learning tool.

Post-test questions

1. Do you think this practice with the haptic back will be of help to you in the development of your palpatory skills in OMM lab?

   ___no   ___maybe   ___yes

2. Do you think further practice with the haptic back would be of help to you in the development of your palpatory skills in OMM lab?

   ___no   ___maybe   ___yes

3. Realism. How well do you think that the simulation of the back reflects the feel of a real back? (Circle one.)

   1   2   3   4   5   6   7   8   9   10
   Unrealistic   Realistic

4. Comments:

Data Analysis

Results from performance tests and practice sessions were analyzed with a repeated-measures analysis of variance (ANOVA). A Bonferroni posthoc analysis was also performed on the results of the practice sessions.

Analysis of the data from the practice sessions posed problems resulting from the fact that not all subjects chose to practice the sessions in order of easiest to most difficult.. After the first few sessions, some subjects skipped the easier levels and went directly to the harder levels. Other subjects stuck primarily with the less difficult levels at which they felt competent. This resulted in missing data points both at the easier levels and at the more difficult levels.

We approached this absence of data in two different ways. One way was to eliminate subjects with missing data points, which would bring the total number of subjects down from 21 to 14. The other way was to fill in missing data points, which was done in the following way. If subjects had shown they were able to locate abnormalities in the easy levels correctly in early practice sessions, they were credited with doing them correctly in later practice sessions\sc1\even if they did not actually do them. At the more challenging levels, where subjects had not made correct localizations, they were scored as making incorrect responses even if they had not tried those levels.

Results

Performance tests

The accuracy of localizing the dysfunctional areas increased significantly (P<.05) at difficulty levels 0.7, 0.8, and 0.9 between the pre-test, taken prior to the eight practice sessions, and the post-test, taken after the practice sessions (Fig. 6). No statistically significant improvements were seen at the easiest level, presumably because performance at this level was quite high even in the pretest. Likewise, no statistically significant improvements were seen at the most difficult level that was tested (0.95), presumably because the task was simply too hard for students to master. At this level, performance remained at near-chance levels. Speed improved at all levels of difficulty (*Figure 7*).
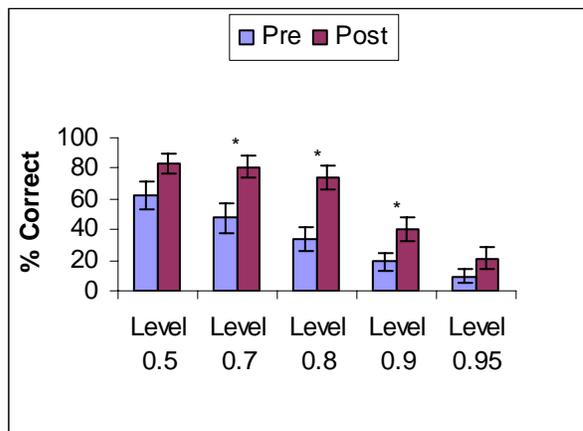

Figure 6. Subject accuracy on the pre- and posttests of the Virtual Haptic Back at five different levels of difficulty. *Statistically significant pre- to posttest differences (*P*<.05) occurred at the intermediate levels of difficulty, but not at the easiest or most difficult levels.
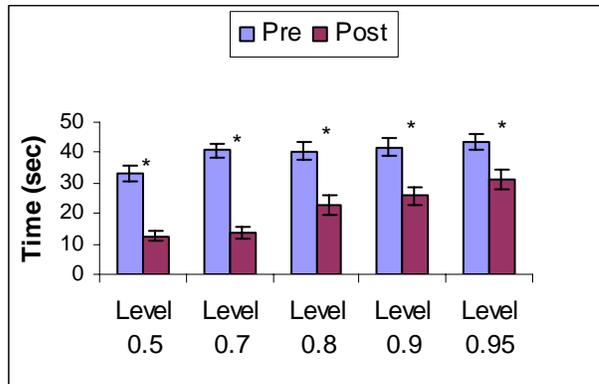
Figure 7. Time to task completion on the pre- and posttests of the Virtual Haptic Back at five different levels of difficulty. The maximum time allotted for each trial was 1 minute. At all five difficulty levels, the reduction in time to completion was statistically significant(P<.05).

Practice Sessions

Data from the practice sessions for all 21 subjects are shown in Figure 8. At the easiest levels, users performed very well even in the first practice session. At the most challenging level, student accuracy improved with successive practice sessions, but remained at near-chance levels throughout. The most dramatic improvement is seen at intermediate levels of difficulty. Subjects performed poorly during the first practice sessions, but did progressively better in successive sessions. Repeated-measures ANOVA indicated statistically significant differences (P<.05) across visits and across difficulty levels as well as a significant interaction term. Bonferroni posthoc analysis[10] indicated that (1) the results of the first practice session are statistically different from the results of all subsequent sessions; (2) the second and third practice sessions are statistically different from later sessions; and (3) the fourth through eighth sessions are not statistically different from each other. Although these observations generally corroborate the impression one gains from *Figure 8*, the requirements of repeated-measures ANOVA with respect to sphericity and normality of the data set were not met.
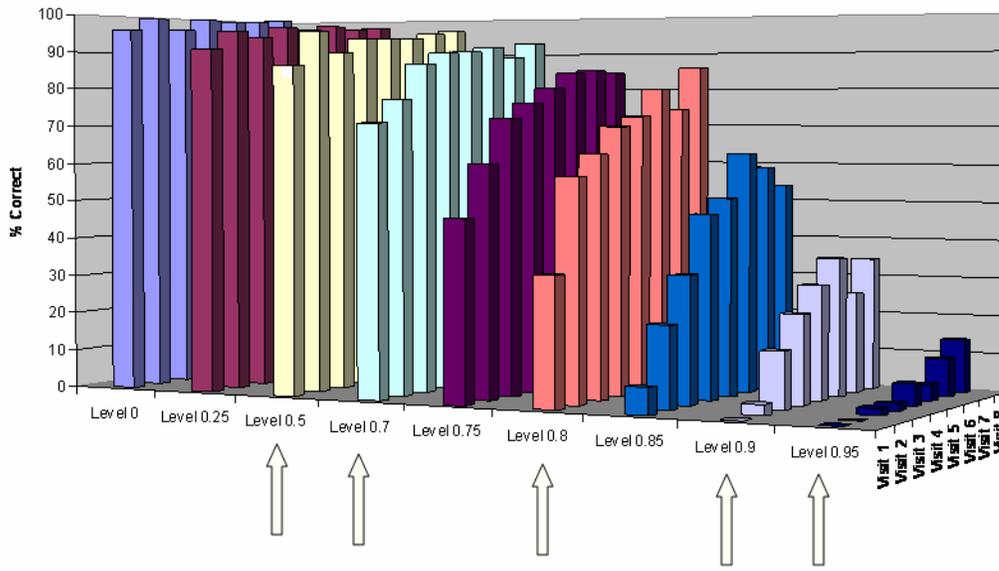
Figure 8. Student accuracy (% correct) at nine different difficulty levels during the eight practice sessions (N=21) on The Virtual Haptic Back. The successive practice sessions (front to back) are labeled "visits." The arrows indicate difficulty levels used in the pre- and posttests.

To meet ANOVA requirements, we analyzed a subset of the data, using results from only the 14 subjects who tried all **nine** difficulty levels, starting with the easiest up to the hardest levels they attempted in each session, leaving no missing data points (*Figure 9*). The same general pattern is evident in this subset as was seen with the entire population (*Figure 8*), and repeated-measures ANOVA revealed highly statistically significant differences between performance during the first four sessions compared to the last four (*P*<.001). There was also a statistically significant interaction period (*P*=.024), indicating that the change in performance between the first and last group of sessions varied with difficulty level (ie, only at the harder levels did improvement occur with practice).
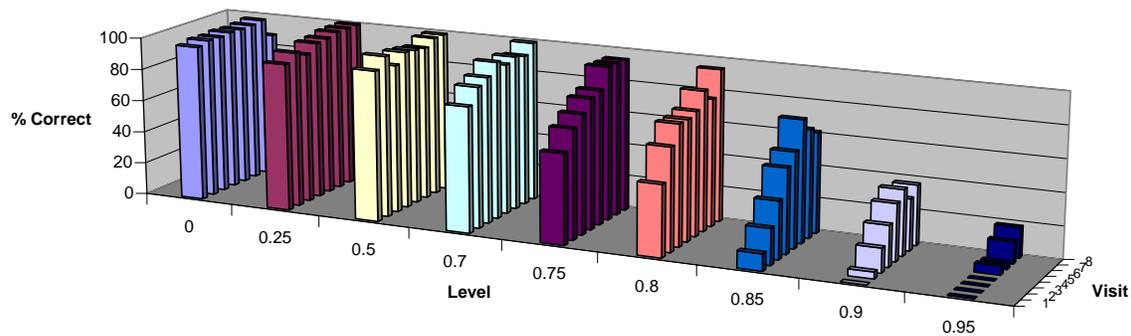
Figure 9. Subject improvement in performance accuracy in The Virtual Haptic Back over the eight practice sessions and across nine levels of difficulty (N = 14).

Survey

Students responded to a brief survey after completing the Virtual Haptic Back posttest.

1. Do you think this practice with the haptic back will be of help to you in the development of your palpatory skills in OMM [osteopathic manipulative medicine] lab?

2. Do you think further practice with the haptic back would be of help to you in the development of your palpatory skills?

3. How well do you think that the simulation of the back reflects the feel of a real back?

Of the 21 subjects, 17 (81%) marked "yes" and 4 (19%) responded "maybe" on the first question (none of the students answered "no"). On the second question, 12 students

(57%) marked "yes," 8 (38%) answered "maybe," and 1 (5%) responded "no." Using a

Likert scale, the students were also asked to rate the realism of the simulation, with 0

being very unrealistic and 10 being very realistic. The mean rating was 6.5.

COMMENT

Both the objective results obtained in this study and the subjective responses of students indicate the potential value of the VHB as an aid in learning palpatory diagnosis. Data from the pre- and posttests indicate statistically significant skill improvement ($P<.05$), and the data from the practice sessions reveal the pattern of improvement. The subjects in the study were first-year osteopathic medical students taking a course in OMM at OU-COM, where OMM training occurs over the course of 2 years and consists of 2 hours of practical training weekly in a lab supplemented with occasional lectures. The VHB study was carried out during the fall and winter quarters in 2005 during the early stage of students' palpatory training.

Some of the subjects' skill improvement between the pre-test and post-test undoubtedly resulted from familiarization with the unusual environment of the haptic simulation. The jump in performance level between the pre-test and the first practice session reflects that familiarization process. However, the near 100% performance at the easiest level in the first practice session, suggests that the novelty of the situation did not prevent the subjects from detecting obvious compliance differences. Another difference between the tests and practice sessions was that only during the tests was a time limitation imposed for each trial. This may have contributed to greater levels of accuracy achieved during the practice sessions at difficulty levels 0.5 and 0.7 than during the posttest. It is interesting, however, that at the higher difficulty levels users did not do better during practice than during the timed post-test. The gradual improvement seen over the successive practice

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sessions at difficulty levels 0.7 through 0.85 suggests that real skill improvement was taking place with practice.

In typical psychophysical experiments designed to determine the sensitivity of any sensory system, a large number of trials is typically carried out, simply asking subjects to determine which of two inputs is larger than the other.[2] In the case of detecting compliance differences, for instance, subjects are typically asked to compare the compliances of several different test objects with that of a reference object. When the compliances are very close to that of the reference object, subjects will not be able to distinguish between them and are correct only 50% of the time (chance level). When the differences are large, they are correct 100% of the time. Generally, the just-noticeable difference is taken as the level at which correct identifications are made 75% of the time (ie, halfway between chance and certainty). Experiments of this type have been done on the ability to detect differences in compliance of real objects[11] and of virtual objects.[3,4] As previously discussed, compliance detection of virtual objects or surfaces has been done with the PHANTOM haptic interface, and has yielded Weber fraction estimates as low as 0.08 to 0.12 with time-invariant surfaces.[4]

In the current study, the smallest compliance difference detectable is judged by correct localization of the abnormal area of the back and the chance value is far less than 50%. The actual area that is abnormal, 7.5 cm^2, constitutes only 2.5% of the area in which the palpation is done. However, there are only 12 different sites where the abnormality can occur in the Virtual Haptic Back. Assuming the students knew the location of those

twelve sites, and if they were applying only one finger for identification of the abnormal

area, the chance level would be 1 in 12, or 8.3%. However, with two-finger palpation, the

student could have been touching two different areas at once when he or she hit the foot

switch. If either finger is on the correct area, the user is credited with a correct answer.

That could, in principle, raise the chance level to 1 in 6, or 17%. Thus, chance level may

have varied among students depending on their approach. We have chosen 20% as a

conservative estimate of chance level, although it must certainly be lower than that.

Using 20% as chance level, we can take the performance level of 60%, as the just-

noticeable difference (again, half-way between chance [20%] and certainty [100%]).

During the pretest, the 60% criterion for the just-noticeable difference was achieved only

at the easiest tested level, difficulty level 0.5 (imagine a horizontal line at 60%

representing master level in *Figure 6*). This corresponds to a Weber fraction of 0.40

(40%). During the posttest, the criterion was met at the 0.8 level, corresponding to a

Weber fraction of 0.11 (11%). During the first practice session, performance at difficulty

levels of 0.7 or less reached the criterion level, corresponding to a Weber fraction of 0.21

(21%). During the sixth practice session, the 60% level was achieved at the 0.85

difficulty level, corresponding to a Weber fraction of 0.09 (9%). This falls in the range

obtained by DeGersem,[4] who used a standard psychophysical design in which subjects

palpated two smooth surfaces and judged which surface has the higher compliance.

However, the task in our experiment was more complex in that (1) the areas of abnormal

compliance first had to be searched for and found, and (2) the abnormal compliance was

superimposed not on flat surface but on a surface with the complex contour of the human

back. Further studies are needed to determine if a training effect, as we observed, would also be observed in the simpler experimental paradigm.

It is interesting that the data seem to reveal performance improvement with successive practice sessions even at the 0.9 and 0.95 difficulty levels, with Weber fractions of 6.7% and 2.8%. At these levels the 60% mastery criterion was not reached, but the improvement seen raises the question as to whether further practice would have permitted users to reach that criterion level.

Several of the subjects were enthusiastic about using the VHB, indicating that it would have been particularly helpful even earlier in their OMM experience. They recommended that all first-year students be given an opportunity to use it. Subsequently, in fall 2006, the VHB was incorporated into the OU-C OM curriculum. Data from that study have been submitted for publication. Based on those data some modifications have been made, and the modified VHB will be used as a required element in the curriculum in the fall of 2007.

It is our experience that osteopathic medical students often lament the paucity of supervised practice time in palpatory diagnosis and manipulative medicine, time that would provide feedback about the correctness of their palpatory impressions and manipulative techniques. The immediate feedback provided by the VHB fills this need with regard to palpation, allowing students to develop confidence in their palpatory

abilities. It also allows them to explore different modes of palpation, (eg, use of different fingers to find out which works best for them).

The VHB represents an accurate model of palpation of the human back in the sense that the compliance values used in the model are in the range of those measured on human subjects[5] and the palpatory forces are in the same range as those used by osteopathic physicians examining real patients.[9] In its present state, however, the VHB simulates only the most rudimentary element of tissue texture change, namely a decreased compliance of tissues in a single area.

Patterns in real backs are far more complex,[13,14] and skill in palpatory diagnosis involves not only detection of tissue texture changes, but also interpretation of these changes in the context of complex patterns. Work is currently underway to make the VHB reflect these patterns. One step is the programming of several haptic backs, reflecting palpatory differences with age, sex, and body habitus. Another is to incorporate some of the more complex patterns of tissue texture change, reflecting such elements as mirror image asymmetries and multiple segment interactions as described by William L. Johnston, DO.[13] Work is also underway to permit the input of gross motion with one hand moving a simulated arm or shoulder, while the other hand palpates corresponding tissue texture responses in the back. These efforts are intended to extend the usefulness of the VHB simulation.

CONCLUSION

Eight 15-minute training sessions on the Virtual Haptic Back permitted osteopathic

medical student users to improve their ability to discriminate compliance differences

from a 40% difference to an 11% difference. The training effect, represented by the

performance improvements in both speed and accuracy, coupled with the positive

endorsements by student users, suggests that the VHB can serve as an effective teaching

aid for palpatory diagnosis.

References

1. Jones HJ. Somatic dysfunction. In: Ward RC, executive ed. *Foundations for Osteopathic Medicine*. 2nd ed. Baltimore, Md: Lippincott, Williams & Wilkins; 2003:1153-1161.

2. Gescheider, GA. *Psychophysics: the Fundamentals*, 3rd ed. Mahwah, NJ: Lawrence Erlbaum Associates; 1997.

3. Dhruv N, Tendick F. Frequency dependence of compliance contrast detection. DSC-Vol. 69-2. Proceedings of the ASME Dynamic Systems and Control Division. 2000.

4. DeGersem G. Kinaesthetic feedback and enhanced sensitivity in robotic endoscopic telesurgery [PhD thesis]. Belgium: Katholieke Universiteit Leuven; 2005. Available at: https://repository.libis.kuleuven.be/dspace/bitstream/1979/30/2/GDG_PhD.pdf. Accessed August 2, 2007.

5. Streng M, Rockey B, Ji W, Conatser R, Burns J, Howell JN. The Effect of Respiration on Paraspinal Muscle Compliance at T3, T7, and L4. Poster presented at: Ohio University College of Osteopathic Medicine Research Day; September 29, 2006; Athens.

6. Williams RL II, Howell JN, Conatser RR, Burns JM,Eland DC. Palpatory training on the Virtual Haptic Back improves detection of compliance difference. Proceedings of EuroHaptics International Conference, EH2006, pp. 247-250, 2006 (Paper available at http://www.oucom.ohiou.edu/IINR/publications.htm; entire proceedings available through annie.Plaza-Tierno@ibisc.univ-evry.fr).

7. Howell JN, Williams RL II, Burns JM, Eland DC, Conatser RR. The Virtual Haptic Back: detection of compliance differences. Paper presented at: Digital Human Modeling for Design and Engineering; July 4-6, 2006; Lyon, France. (Paper available at http://www.oucom.ohiou.edu/IINR/publications.htm)

8. The Visible Human Project. US National Library of Medicine National Institutes of Health Web site. 2007. Available at: http://www.nlm.nih.gov/research/visible/visible_human.html. Accessed August 2, 2007.

9. Eland DC, Conatser RR, Bajaj, K, Burns J, Majzun, MJ, Howell JN Finger force measurement during palpation. [Interdisciplinary Institute for Neuromusculoskeletal Research (IINR) Web site]. January 2007.Available at: http://www.oucom.ohiou.edu/IINR/pdf/ForceMeasurementResults.pdf. Accessed August 2, 2007.

10. Stevens J. *Applied Multivariate Statistics for the Social Sciences*. Hillsdale, NJ: Lawrence Erlbaum Associates; 1986:6-8.

11. Srinivasan MA, LaMotte RH. Tactual discrimination of softness. *J Neurophysiol*. 1995;73:88-101.

12. Johnston WL. Development of a functional orientation for technique. In: Beal MC, ed. *50th Anniversary Convocation of the AAO Yearbook*. Indianapolis, Ind: American Academy of Osteopathy; 1992:51-61.

13. Kuchera ML. Examination and diagnosis: an introduction. In: Ward RC, executive ed. *Foundations for Osteopathic Medicine*. 2nd ed. Baltimore, Md: Lippincott, Williams & Wilkins; 2003:566-573.

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