Using Audio-Tactile Methods to Teach Statistics to Visually Impaired Students

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Abstract: Guidelines for teaching statistics encourage graphical presentation for conceptual understanding. However, blind and visually impaired students can neither appreciate visual representations nor create their own graphs. This paper describes development and testing of a computer product called the Talking Tactile Tablet to present interactive statistical graphics to visually impaired students. The TTT combines tactile graphics mounted on a touch screen with an audio text that explains the graphs and concepts. The system produced gains in statistics exam and self-confidence scores in visually impaired students equivalent to those of sighted students. Future projects include extending the materials to print-disabled dyslexic students.

Introductory applied statistics is required for many majors and careers in the social sciences, physical sciences, and business. Essential to students' understanding of statistics is an appreciation of the pictorial representation of data patterns in the form of charts, graphs and probability distributions, as well as the ways in which these representations illustrate verbally-presented concepts and numerical expressions.

Guidelines for teaching statistics encourage the use of graphical presentation to help students understand concepts and relationships [1]. Students are also encouraged to produce their own graphs and charts in the standard statistics course. However, this presents major accessibility problems to blind, visually impaired, and other print-disabled students. For the

student who is blind, understanding and integrating these concepts is especially challenging. Blind students often find statistics extremely difficult because of the visual nature of so many of the concepts, the lack of accessible graphical materials, and the limited adequacy of verbal descriptions to capture the essence of the visual relationships.

Tactile graphics for blind students are often primitive, done "off the cuff," and not easily understood. Sometimes blind students must rely on verbal descriptions from readers which may be difficult to follow, they may be exempted from graphically intensive courses, or they may be told, "You can skip this topic," only to find themselves missing a concept that is essential for understanding later topics. To the extent that accessible graphics exist, it is often difficult for blind students to move easily between these materials, explanatory texts, and problem solving, let alone to create their own graphs, in a way that allows them to develop the capacity for statistical thinking.

We at the Computer Center for Visually Impaired People at Baruch College, The City University of New York, and at Touch Graphics, a small company based in New York City that develops software for visually impaired people, decided to confront this challenge via a project to developing fully accessible audio-tactile graphics combined with an easy-to-understand introductory statistics text. We did so using an instrument we developed called the Talking Tactile Tablet, a touch screen peripheral on which the student can mount a raised-line graphic which is keyed to an audio description that describes the graphic to them as they touch it. Our project was funded by the Fund for Improvement of Postsecondary Education (FIPSE), U.S. Department of Education, 2003-2007.

The Talking Tactile Tablet

The Talking Tactile Tablet is a touch-screen computer peripheral that connects to a standard USB port. A raised-line and textured (tactile) overlay sheet fits on the TTT and is keyed to an audio program when the user presses an ID strip along the top of the sheet. Once the sheet is initialized, the user can explore the sheet manually and examine a graphic or a formula; when the user presses different parts of the graphic, he or she hears an audio description. A sample illustration and description of the TTT and the statistics courseware can be found on http://www.touchgraphics.com/stat.htm. All tactile sheets for the TTT follow the same standard format, having an ID strip across the top, an "enter" button and arrow keys to navigate the program menus and text on the side, a numeric keypad on the side, and the statistical graphics in the center. The TTT has been used in other projects as well, including a talking atlas of the world, an authoring tool for teachers, and math test-taking programs.

The software product we developed was based on a simple introductory statistics manuscript written by the first author and currently in use as an in-house publication for her section of a liberal arts statistics course at Borough of Manhattan Community College. The text is written in a simple, conversational style, with emphasis on understanding, computing, and interpreting descriptive and inferential statistics as they would be used in a business or social science workplace. All graphics were created using Microsoft Excel. Each chapter follows the same structure: Key Points, Topics, Important Terms, Questions, and Activities (problem solving). Students can enter their answers to the questions and problems by using the computer

keyboard; these can be saved and later accessed by their teacher. Students can access the correct answers only after they have entered their own. For some exercises, the TTT includes spreadsheet functions that sort the data and compute the mean and standard deviation. Other calculations may be performed by the student using a talking calculator separate from the TTT.

The TTT includes template sheets which students can use to create their own statistical charts and graphs. The student can "draw" lines by laying down "Wikki Stix" (http://www.wikkistix.com/sightimpaired.htm), flexible waxed sticks that adhere to the template sheet, or can use adhesive bumps to mark points on the graph. One template sheet looks like a sheet of blank raised-line graph paper and another is a circle with only the "12 o'clock" line, plus tick marks around the clock with audio tags that speak amounts from 0 to 100 percent when pressed. The student can record his or her original graphs by laying down the materials and pressing the appropriate spots until the answers are recorded, for later examination by the instructor.

Procedure

In the first year of our grant, the manuscript was revised and expanded, and was reviewed for accuracy, clarity and coverage by five professors teaching undergraduate statistics at both community and senior colleges. The text was recorded by a live professional reader and the graphics were converted to tactile sheets using computer-aided design software and special machines that create raised-line sheets.

In the second year, the first author taught, with technical assistance from the second author, a pilot class consisting of eight blind and visually impaired students who used the TTT and the software in a computer lab. Ten sighted students, serving as a control group, used the print text in a mainstream class taught by the same instructor.

In our final years, the materials are being disseminated to colleges around the country for use in learning centers and disability services offices by visually impaired students enrolled in mainstream classes. All activities were supervised by the third author, the principal investigator of the grant.

Results

A comparison conducted by an outside evaluator showed that the blind students made achievement gains comparable to those of the sighted students. Before classes began, all students took a statistics knowledge test, developed by the evaluator and approved by the panel of five statistics professors. Students took an alternate form of the test after the course was completed and gain scores were assessed. Visually impaired students showed significant statistics learning gains that were equivalent to those shown by the sighted students. Visually impaired students' mean increase was 10.29 points on a 38-point scale ($p<.004$), as compared with 11.6 points for sighted students ($p<.001$). Gains in graphical knowledge were also comparable and significant; the difference between mean gains made by blind vs. sighted students was not significant.

Students also made significant gains on a questionnaire measuring self-confidence in learning statistics that was developed for the study. Visually impaired students' mean increase was 2.0 points on a 7-point scale ($p<.001$), as compared with 1.7 points for sighted students ($p<.001$).

Finally, a focus group was conducted with the visually impaired students to gather their opinions on their experience with the TTT. Students made suggestions for modifying or improving various features of the TTT. They also said the TTT was enjoyable to use and was highly successful in bridging the gap in their understanding of visual statistical material. In the words of the students: "I wouldn't have done well in this statistics class without the TTT. It helps you to move at your own pace. I have had to drop statistics class before." "I am blind from birth; hence, there is no third dimension. The TTT helped me to visualize the graphs better."

Conclusions

The results of our pilot class show that audio-tactile presentation of statistical material is successful for improving statistics learning in blind and visually impaired students, as well as for improving their self-confidence in learning statistics. The electronic format of the TTT is especially useful for accomplishing these goals in a way that is interactive, comprehensive, and engaging to the user. In our final years of the grant, we are disseminating the materials to colleges where blind and visually impaired students are currently taking statistics. These materials will be administered through the colleges' disability services offices as a study aid outside of classes, in some cases with the aid of a trained tutor. We are continuing to collect evaluation data and comments from these students that will be used to modify and improve the product.

Our work has also revealed an important learning issue with visually impaired students: because of years spent without adequate graphical experience, they have accumulated deficits in spatial understanding that require more intensive work to overcome than mainstream students need. We observed that our visually impaired students required more time on task, with more individual attention and explanation, than sighted students to achieve comparable gains. However, our work also showed how interactive audio-tactile graphics can be powerful in bridging that gap. Future plans include expanding the materials using this format and extending the trials to sighted but print-disabled dyslexic students, in order to make mathematical material fully accessible to them as well.

Reference

1. ROSSMAN, A. J., & Chance, B. L., *Teaching the Reasoning of Statistical Inference: A "Top Ten" List,* **COLLEGE MATHEMATICS JOURNAL, Vol. 30, No.4,** pp297-305, Sept.(1999).