

Airong Xu. Eye Tracking Study on Identifying and Analyzing User Behavior - Eye Movements, Eye Fixation Duration and Patterns - When Processing Numeric Table Data in Paper or PDF Format. A Master's paper for the M.S. in I.S. degree. November, 2000. 60 pages. Advisor: Gary Marchionini

This study describes an eye tracking experiment conducted at the Interaction Design Lab of UNC-CH. This experiment focuses on identifying and analyzing user behavior and patterns when processing numeric table data in paper or PDF format. Eight sets of eye data were collected using the ASL 504 eye tracking system, and raw data were analyzed using EYENAL and FIXPLOT software.

Statistical literacy and familiarity with tables is an important factor in determining users' search performances. For both formats, table column and row headings account for nearly half of users' visual attention during search as measured by fixation duration. In large tables, PDF files do not appear to be appropriate for browsing and searching, and footnotes seem hard to use. Simple manipulations over table data are helpful for users to get a better understanding of statistical tables.

Headings:

Eye tracking

Eye movement patterns

Statistical tables

Tabular data

User information-seeking behavior

EYE TRACKING STUDY ON IDENTIFYING AND ANALYZING  
USER BEHAVIOR - EYE MOVEMENTS, EYE FIXATION DURATION  
AND PATTERNS - WHEN PROCESSING NUMERIC TABLE DATA  
IN PAPER OR PDF FORMAT

by  
Airong Xu

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Approved by:

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Advisor: Dr. Gary Marchionini

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## CHAPTER 1: INTRODUCTION

This eye-tracking study is part of the table browser project supported by the National Science Foundation and involves several government agency partners as well as partners at other universities. The goal of the project is to understand the nature of e-tables and develop interfaces for using them. The project will develop a new tool that can enhance the understandability and usability of large online tables and make it easy for untrained citizens to browse statistical tables (Mu, 2000). In order to make the table browser interfaces easy to use, we must have an understanding of how people read and process statistical tables and how the electronic medium (online tables) affect their use of tables. At present, based on the table browser prototype, usability studies have been carried out to test the usability of table browser interface prototypes by comparing the ease of use between two formats of statistical data: a flat tabular presentation in electronic form (PDF) and a dynamic tabular presentation in the table browser's interface. This eye-tracking study focused on identifying and analyzing user behavior - eye movements, eye fixation duration and patterns when processing (reading, analyzing) numeric table data in a flat tabular format (paper/PDF). This study provides a better understanding of how humans process numeric data in tabular format. A second benefit is recommendations for the development of effective and efficient user interfaces for processing table data.

It has been said that eyes are the windows to the soul. Eye positions and movements are the result of the internal information processing performed by the brain and visual system. Eye fixation refers to a person's point of regard as he/she looks at a still target in a visual field. Eye fixations are primarily distinguished from saccades and other types of very small eye movements (jitters), which occur during fixation.

The eyes are rarely still, and generally can't move smoothly over visual fields. Saccades - rapid conjugate eye movements - occur when a person changes fixation from one point to another. Saccades typically cover 15 to 20 degrees, and take between 30 and 120 msec. Total latency is of 100 to 300 msec in response to a visual stimulus. The delay between saccadic eye movements is 100 to 200 msec, and after a saccade, the eyes will fix on an object between 200 to 600 msec. Even during a fixation, people think they are looking at an object steadily, the eyes still engage in small motions within one degree. The jitter motions include high frequency tremor and drift from a fixation; the drift is then corrected by a micro saccade, which prevents creating a fixed image on the retina, because the stationary image will fade from view after a few seconds (Pritchard, 1961).

Other types of eye movements are nystagmus (smooth pursuit motions), vergence, and torsional rotation (Jacob, 1995), which may be very useful for other studies or applications; however, we did not see them in our study. In our case, a user sat before a desk top computer monitor reading static table data on paper or electronically. We expected to see steady or jittery fixations connected by sudden, rapid saccades during the test period. For this study, a series of saccadic eye movements and points of gaze

(fixations) were collected, and then analyzed using the EYENAL software to describe the general patterns of eye movements when people browse and search table data in a tabular form.

## CHAPTER 2: BACKGROUND INFORMATION

### **Why Tables**

There are various forms of presenting statistical information to the public, such as tabular, textual, and graphic forms. Among these forms, tables provide a convenient method to represent masses of numerical data in a straightforward tabular form. As Washburne concluded, the form or method of presentation is a significant factor in the comprehension of statistical data, and tables are better in helping people recall specific values (Washburne, 1927). Later studies suggested that short, simple tables are better than long, detailed tables in presenting numerical data to people who are not familiar with statistical presentation in tabular methods, but for people who have knowledge or experience in using such methods, short and long tables may be used equally effectively to present the statistical information (Feliciano, et al. 1963).

Tables are widely used in our day-to-day lives. For example, people are usually familiar with nutritional labels on cereal boxes, stock price tables on newspaper, and time schedule tables for airlines and buses. Moreover, many people have used spreadsheets to store and manipulate table data. In the business world, tables have been used in various kinds of reports and forms, such as invoices, inventory lists and so on. Also, multiple federal government agencies have provided various recourses and statistical information

in table format to facilitate citizens' usage. Agencies such as the Bureau of Labor Statistics, Bureau of Transportation Statistics, and National Center for Health Statistics provide a variety of data, including employment and unemployment data, annual income, financial data, tax data, information on the Nation's transportation systems, health resources data, and many more.

### **Displaying Government Statistical Data on the Web**

Government statistical information is important to citizens' ordinary lives, because the data they get can help them make better personal decisions, for example, job hunting and relocating. They need to access, retrieve these data, and then take action based on it. From the users' point of view, they want faster, easier, and less expensive access to statistical information through media that are better adapted for their own processing needs. The World Wide Web (WWW) offers such an effective approach for citizens to access government statistical data, and there is a growing trend toward the dissemination of such data by electronic means (e.g. Internet, online databases). More than 70 agencies in the U.S. Federal Government produce statistics information for the public, the Fedstats Web site (<http://www.fedstats.gov/>) contains a full range of statistics and information produced by these agencies for public use. However, people not only need to access government statistical data but also need to understand, manipulate and use these data. To do so, "the data must both be easy to find and easy to interpret and use" (Marchionini, 1998), and the software used to retrieve and display the data from the electronic media must meet the information-seeking behavior and cognitive frames of a diversity of users. The user interfaces for such software tools must be understandable, effective and efficient

to use, as stated in Coll's cognitive match interface design principle (Coll & Coll, 1989), which argues that the system should be able to interact with users in a manner that parallels the flow of the user's own thought processes. Furthermore, previous surveys showed that many users of such online software systems are casual and naïve users (Hyland, Hasan & Fuentes, 1996). Interface designs that allow such users to explore and manipulate data rather than simply posing well-organized queries are appropriate alternatives. The various levels of statistical knowledge and information literacy of individual citizens result in a wide range of problems related to how they read table data.

### **Problems on How People Read Tables**

The problems on how people read tables might be classified into three categories: user, data and media (Marchionini, 1999). The user problems include user cognitive style and user literacy, such as computer literacy, statistical literacy, understandability of terminology, etc. We can't assume users can learn complex search skills in tables by using the interface frequently, since most users do not have high-level statistical literacy. The data problems include metadata availability, data format and data compatibility. Carefully documented metadata support table understanding and are necessary for good interfaces. The media problems include the difference between paper and electronic formats, and the limitations of screen real estate.

## **Eye Movements Measurement Techniques**

The eyes do not move randomly, research has shown that eye fixations indicate what people are working on (Just & Carpenter, 1980). People gaze at certain object in conjunction with other activities, such as manipulation, and “eye gaze contains information about the current task and the well-being of the individual.” (Sibert & Jacob, 2000). So eye gaze can be used as reliable indices of the point of visual attention. Eye tracking system measures the visual gaze direction – the absolute locus in space at which the user’s eyes are pointed (Jacob, 1991). Since both eyes point together, it is OK to track only one eye. Eye tracking is the most detailed measurement of eye movements, and it has been widely used in physiology studies on reading and human computer interaction studies.

Many techniques (Young & Sheena, 1975) have been used for the detection of eye movement. Earlier measurement techniques require the subjects be constrained somehow from moving, such as EOG (electrooculography) and eye coil. The new generation of eye trackers eliminates subject’s immobilization by measuring eye gaze in a head-free condition. The ASL 504 eye-tracking system used in this study doesn’t require the subjects’ heads to be fixed by distinguishing head movements form eye movements.

EOG works by quantifying the corneal-retinal potential, a small voltage between the front and back of the eye that is correlated with eyeball movement and obtained by electrodes placed on the skin near the eye. Eye movements can be recorded on a simple chart recorder or a computer. The advantage of EOG is low cost and simplicity (not requiring

visualization of the eye). However, the setup is slow due to skin preparation, light adaptation and careful application of electrodes. Although vertical recording is possible, it may be confounded by eye blinks. EOG is more useful for measuring relative eye movements than absolute position, it can cover eye movements up to  $\pm 70$  deg (Wolf & Knemeyer, 1969), although linearity turns out to be considerably worse when eye excursion is greater than 30 deg, especially in the vertical (Young & Sheena, 1975).

Contact lens with coil (Eye Coil) is an extremely accurate method if the subjects are willing to put contact lens on their eye with a little wire coming out of it. This method is practical only for laboratory studies, it has good vertical recording and linearity capabilities. The combination with sclera coil contact lenses can record 3D eye or head movements (i.e. horizontal, vertical and torsional movements). But all contact lens cause discomfort, and there is a small risk of corneal abrasion from the contact lens. It seems that the eye coil technology is most suitable for animal research, not for wide spread investigation on the normal population.

Infrared reflection (IR) generally works by quantifying the difference between the amount of infrared light reflected by the sclera between a sensor pair. IR has less noise than EOG, set up is fast and calibration is needed. The problem with IR is that it only works well with the eyes close from center, and linearity is also a major problem.

Of the eye-tracking techniques currently available, the least obtrusive one is the corneal-reflection/pupil-center distance method, which measures eye fixation point of the

participant without requiring any head position measurement or stabilization. Computer based systems can track head motions and have auto focus function. This method is comfortable; data is in a form easy for processing, and linearity is improved. The limitation is speed, which is at most 60 samples/sec, and accuracies are not so good as contact lens (Young & Sheena, 1975).

Eye tracking studies have been done mainly in three areas: in human factors studies for the military; in research on psychological processes and cognitive research dealing with reading; and in bioengineering helping disabled people in communication (Bolt, R.A.). More than 120 years ago, Javal discovered that the eye made a series of discrete jumps (saccades) connected by pauses (fixations) when studying young children's eyes during reading (Mackworth, 1974). From then on, subsequent psychological research focused on the jumps rather than the pauses. In the recent a few decades, there has been much research interest on the fixations and how they related to underlying cognitive processes (Tichomirov & Posnyanskaya, 1966). Also, eye-tracking techniques have been used in human computer interaction studies, such as using eye-gaze as input to facilitate interaction between user and the computer, help user run software applications and manage other devices simply by looking at certain menu options on the screen (Hutchinson, 1989). Although results (Ware C. & Mikaelian H.H.) showed that an eye tracker can be used as a fast selection device with moderate target size, it is regarded as far from "perfect" because of the limitations of current equipment and the nature of human eye movements (Jacob, R.J.K., 1995). Though eye data is very low-level data, it has the potential to provide additional data to comprehensive studies of human behavior,

and eye movement protocols have played an increasingly important role in such studies due to the improved eye-tracking equipment and the assistance of raw data analyzing software.

## CHAPTER 3: METHODOLOGY

### **Facilities**

In this study, the Applied Science Laboratories (ASL) model 504 eye tracking system was used to study people's information processing behavior on table data, with a specific emphasis on browsing and searching tasks.

The eye-tracking equipment includes the following components:

- ASL Model 5000 Eye Tracker Control Unit and plug in power supply
- Pan/Tilt optics eye camera optics module (Sony video camera)
- Remote scene camera (Costas)
- Eye tracker interface PC
- Flock of Birds Head tracker electronics unit, magnetic transmitter, head mounted sensor & halo
- Two black and white video monitors (eye monitor and scene monitor)
- Scan-Do 1024 Video Scan Converter (resolution up to 1024x768 in 16 million colors, replaces remote scene camera)
- 90MHz Dell Pentium 90 with MS-DOS 6.0 for interfacing with eye & head tracking equipment

- Dell Pentium II 400MHz PC, 19" monitor, Windows NT 4.0, SILS Lab Software Setup
- Cables
- Software
  - a. The E5000 EYEPOS software package to operate the eye tracker and record data.
  - b. EYENAL data analysis software, which can convert binary data files to ASCII, and ACCESS software to access binary data files from user written C programs.

### **The Eye-tracking Environment**

The user sits at a conventional desk with a 19-inch computer monitor, mouse and keyboard. In order to minimize the subject's ability to shift and fidget, we use a stationary wooden chair. The pan/tilt optics module sits on a plastic holder right in front of the monitor. The room lights are dimmed in order to prevent the user's pupil from being too small, and to reduce the monitor reflection. Also, this experiment requires the room lights in the test room not to directly irradiate on the computer monitor, so we placed one table lamp on the left side of the subject and another table lamp behind the subject.

### **How the Eye Tracker Works**

The eye tracker measures a person's pupil diameter and point of gaze on a stationary scene space, such as a computer screen. Point of gaze is computed from the relationship

between the center point of the pupil and the corneal reflection, which are displayed as a set of cross hairs superimposed on the system's eye monitor. The pan/tilt optics module provided with the system can be positioned 18 to 40 inches from the subject's eye. The module consists of an eye camera with a ring of near infrared LEDs (Light Emitting Diode) around the lens opening. The LEDs emit an illumination beam that is trained on the retina; the optics module lens captures the light that is reflected back, resulting in a brightly lit image of the pupil. The optics module also captures the reflection of the illumination beam from the surface of the cornea - the corneal. An auto-focusing lens system in the module focuses a telephoto image of the eye onto a solid-state video sensor (eye camera). The pan/tilt mechanism can rotate both the illumination source and eye imaging components in azimuth and elevation to follow the eye as the subject moves about. In addition, a magnetic head tracker is used in conjunction with the eye tracker to provide position data when the eyes are closed. The eye-tracking data may be recorded digitally on the eye tracker interface PC, which serves as the user interface with the eye tracker and a digital data-recording device, or exported to an external device.

### **Difficulties with Interpreting Eye Movements**

It is often complex and time-consuming to interpret eye movements due to the great deal of noise introduced by individual and equipment variability. In an eye-tracking experiment, only a few trials of a simple task can generate huge amounts of data, also it is hard to recognize the difference between unconscious eye movements and attention. Eye movements require little conscious effort, but the position and duration of eye fixations may indicate the area of interest for the subject, they provide a way to explore and

describe the subjects' focus of attention. Evidence shows that there is difference in reading strategies between poor readers and good readers. The differences also exist between novice and experts in reading text and graphics. Vonder Embse (1987) found that expert viewed graphs with a smaller number of longer fixations while novices used a larger number of short fixations.

### **Subjects**

10 subjects were selected from the University of North Carolina's student body, based on email advertisements. Subject included people with statistical experience and those with no statistical experience. Additional subject data collected included age, sex, computer/software literacy and frequency of using statistical tables. Martha Crosby and Jan Stelovsky's discovered that both expertise and cognitive style play a significant role in computer users' comprehension, fixation duration and patterns (Crosby & Stelovsky, 1990). It was hypothesized that these user characteristics would contribute to their browsing and analyzing patterns. The participants were paid \$25 for participation.

A pre-test questionnaire given at the beginning of the study elicited subject characteristics. A post-test included a few brief questions about subjects' reactions to this eye-tracking study, their comments and suggestions. Subjects participated individually and took about one hour for the full treatment.

## Tables and Tasks

Four tables were used in the test, two population tables, and two life expectancy tables. The population tables present statistical data on the growth, distribution, and characteristics of the U.S. population. The source of these data is the Bureau of the Census. The life tables show the life expectancy and survivorship by age, race, and sex, they are current abridged life tables for the U.S. based on age-specific death rates in 1996. The data used to prepare the abridged U.S. life tables for 1996 are final mortality statistics for 1996 and the July 1, 1996, population estimates by the U.S. Bureau of the Census. Table 3 used in the test is a life expectancy table, which contains data for expectation of life at every single year of age (from 0 to 85), by race and sex. Estimated average length of life in years, by race and sex are shown in life table 5. Table 14 is about resident population by age and sex, from 1980 to 1997. Table 26 has the resident population data ordered by states from 1970 to 1997.

There were three levels of tasks.

Task level 1: simple searching questions.

Questions:

1. (table 3) In 1996 how many more years was a 50-year-old woman expected to live?
2. (table 14) In 1997 what was the resident population of all females?
3. (table 14) In 1988 what was the resident population of the 15-19 years age group?
4. (table 26) What was the population of Utah in 1994?

Task level 2: requires the user to perform trend analysis in the data.

Questions:

1. (table 3) Across all groups, what happens to the difference in life expectancy between males and females as people age?
2. (table 5) What happened to the difference in age expectancy of males and females between 1929 and 1996?

Task level 3: requires the user to perform a simple calculation and compare information from separated columns, or requires the user to pay attention to the footnote.

Questions:

1. (table 14) In 1990, by what amount in the total population has the data been adjusted?
2. (table 26) Compared to the population information from 1997, which two states have decreased in population size since 1970?

Appendix 7 shows the full set of questions. There is a little variance on some of the questions, for example, in the PDF format for question 4 - what was the population of Utah in 1994? The subject could not see Utah on the screen, they must scroll down to find it. In some cases, to record the exactly eye movements without any scrolling, the question was changed to “What was the population of New Jersey in 1994?”, also the subjects were told not to use the scroll bar but rather use the mouse wheel when necessary.

PDF files were displayed on the monitor. The paper versions were pasted on the monitor's screen filter, which is almost an inch above the monitor. Usually, people read paper 12-14 inches from their eyes, but during this study, they sat at a fixed chair and their eyes were 28 inches away from the filter. We enlarged the font of the paper data by 50% to partially compensate. Since we don't have a Frame Grabber installed, the PrintScreen key was used to capture a screen shot for each table. This was easy when dealing with PDF files, for paper versions, a more detailed adjustment was required. First, one PDF copy for each paper version was made with exactly the same font size; second, each PDF file was captured then stored as bit map files for further usage in drawing fixation plots; third, during the test, the PDF file for each paper version was opened, then the paper was pasted right above the PDF file on the screen filter.

## **Procedure**

The steps for the eye tracking process can be grouped into three sets. The eye-tracking process flow chart is attached in Appendix 2.

*Calibration of the system's components:* (needs to be done only once for any given physical setup of the components)

1. Setting up calibration target points
2. Set and check calibration target points
3. MHT pan/tilt tracking calibration
  - Transmitter to optics calibration
  - Sensor to mirror calibration

*Subject setup and calibration:* (must be done for each subject used with the system)

Before the subject calibration, give a few minutes for the subjects to read the instruction notes, and ask any questions. Let them get familiar with the table layout and other general information, such as selecting tables, zooming in and out. More information about instruction notes can be found in Appendix 5 and 6.

1. Set the offset value between the subject's eye and the sensor attached to the headband. Obtain an eye image on the eye monitor.
2. Pupil and corneal reflection discrimination
3. MHT pan/tilt tracking
4. Subject eye calibration and calibration test

*Data recording:*

1. Select "New" from File menu
2. Enter file name " xxx.eyd "
3. Select "Begin" from File menu, type number (0-9) to insert event marks, or use "Event Mark" from File menu.
4. Type "S" to suspend, "R" to resume
5. Select "Close" to stop.

## CHAPTER 4: RESULTS

10 subjects participated in this eye-tracking study, including four females and six males. One female subject's eye couldn't be tracked because of the strong reflection of her glasses, she didn't participate in the question answering part. Another subject's eye data has been discarded due to too much noise. Thus, 8 of the 10 subject data were deemed usable for the purposes of this study. The results will be addressed in detail in the following sections.

### **Subject Demographics**

#### *Subject General Information*

The subjects' ages range from 25 to 54. Among these subjects, three wear glasses and one wears contacts. Four subjects (50%) have taken a statistics course either in college or in graduate study; the other four subjects haven't taken any statistics courses. Only one (12.5%) of the eight subjects has ever used Fedstats ([www.fedstats.gov](http://www.fedstats.gov)). Three (37.5%) of them have never used table data from government Web sites, others have used it occasionally. Seven out of the eight (87.5%) have occasionally used statistical tables on the Web, while the other one has never used them on the Web.

### *Computer Literacy*

All the subjects use computers daily. As reflected in Table 1, all of subjects said they have used computers for Email, Word Processing, database, and Web surfing. Four subjects (50%) have used it for games, six subjects (75%) have used it for multimedia applications, and five subjects (62.5%) have used it for programming.

<b>Application</b>	<b>Number of Valid Respondents</b>	<b>Percent of Valid Responses</b>
Email	8	100%
Word Processing	8	100%
Web Surfing	8	100%
Games	4	50%
Database	8	100%
Multimedia	6	75%
Programming	5	62.5%
<b>Total</b>	<b>8</b>	<b>100%</b>

Table 1. Responses to Pre-test Question 2, “What applications do you use?”.

### *Statistical Literacy*

Table 2 illustrates the responses from subjects regarding their statistical software usage. A majority of the subjects said they have used “Excel or other spread sheet”. However, only one subject has ever used SAS, one has ever used SPSS, and the number of people who have others statistical software skills counts 37.5% of the total number of subjects.

<b>Software Package</b>	<b>Number of Valid Respondents</b>	<b>Percent of Valid Responses</b>
Excel or other spread sheet	6	75%
SAS	1	12.5%
SPSS	1	12.5%
Others	3	37.5%
<b>Total</b>	<b>8</b>	<b>100%</b>

Table 2. Responses to Pre-test Question 4, “Please select any statistical software package(s) you have used.”.

### *Familiarity with Tables*

The frequency of table usage can be seen in Table 3, from left to right, the scale can be explained as: no table knowledge, very limited table knowledge, moderate table knowledge and familiar with tables. It is clear that most of the subjects are very familiar with time schedule tables, nutritional labels and research result tables.

Tables	Number of Valid Respondents			
	None	1-5	6-15	>15
Stock market tables/listings	1	3	1	3
Time schedule tables			2	6
Consumer information tables		2	1	5
Nutritional labels		1		7
Research results in articles			3	5
Government statistics on the Web	1	4		3
Tax tables		3	3	2

Table 3. Responses to Pre-test Question 5, “Please tell us how many times you have used the following tables (including both paper and electronic formats).”.

Figure 1 shows the distribution of the percentage of valid responses on table usage. Half of all participants said that they have used “stock market tables” 0-5 times (very little usage), half of them said they have used more than 5 times (moderate usage). 37.5% of the participants said they were familiar with “government statistics on the Web”, and half felt they had very limited knowledge about it.

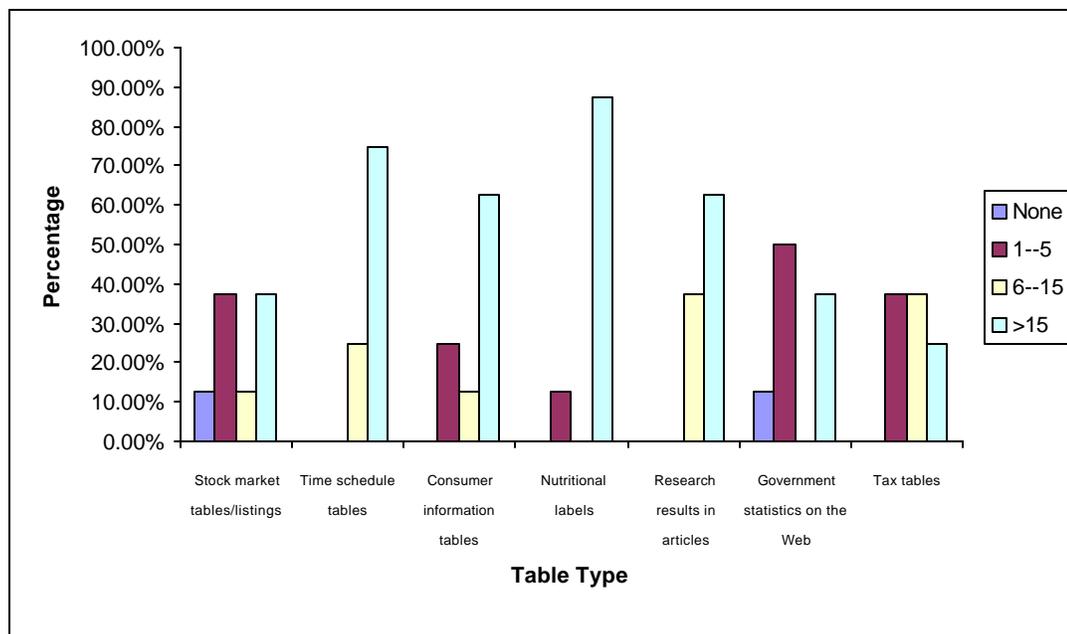


Figure 1. Subject percentage on table usage.

### Expert and Non-Expert

In this study, subjects have very similar computer literacy background. We classified subjects who had taken statistical courses and are familiar with using tables as experts (or experienced users), while regarding those who hadn't taken any statistical courses and have relatively little knowledge in using tables as non-experts (or inexperienced users).

### Post-test Survey

The participants were asked for their comments and suggestions on the study. For each participant, this was his/her first eye-tracking experience. Most of them said it was interesting and comfortable, and they didn't notice the camera was following their eye during the searching. One participant said she liked the eye calibration part. Two of the

eight participants were tested on paper, while others were tested on electronic PDF files. No difficulties were found about reading on paper, most of the problems were related to the PDF files.

Three participants said they had problems with large tables when using the PDF format. They felt large tables were hard to use, and they thought it would be much easier to use in paper, especially for large tables. One participant mentioned that big tables were hard to scroll which made the searching slow, also she said it was a little bit difficult for her to scroll side to side, she would prefer just to scroll up and down instead of in both directions. Another participant thought the screen jumping was annoying, according to his opinion, the screen reset (repainting) is always a problem with reading PDF files, because people have to wait until the repainting has been finished, then can they locate their position. He also talked about the loss of column and row headings when scrolling; in this case, he had to look for a landmark to go back. Two participants said that the purple headings on the PDF files made reading easy. One participant thought that a PDF file is not suitable for online reading because the screen limit with long datasets would cause problems. She also talked about the difficulties she has encountered when looking for the answer to question 8 (the comparison of two states that has decreased in population size), she suggested that if data were pre-sorted (either ascending or descending), it could be much easier for comparisons. Another participant had clicked the scroll bar during the test, after that he lost the table, it took him some time to go back and he also mentioned the loss of the heading bars (e.g. year, age) when scrolling. For people with or without statistical knowledge, they prefer to read statistical table data on

paper instead of electronic PDF files. Even an expert who has lots of experience on tables, spread sheets and Web applications thinks that side scrolling is tricky, and information is not shown until scrolling stops.

Three participants of those who used PDF files said that the footnotes were hard to read (Question 6), because they were not ordered clearly, and not easily accessible. In order to read the whole line they had to scroll side to side.

### **Data Analysis Results**

#### *Make FIX, AOI, FSQ files*

EYENAL Program was used to make eye fixation files and the AOI (area of interests) files using the raw eye data. Eye fixations were computed by FIX function. Point of gaze must continuously remain within a small area for some minimum time, which is usually assumed to be about 100 msec, and the minimum motion is usually assumed to be about 1 degree visual angle.

#### *Image Capture and Fixation Plots*

Using the “Check target Point” selection under the Config menu, the locations of points 1 to 9 were calibrated as coordinates from the computer interface screen. It was h:55 v:43 for point 1 and h:204 v:178 for point 9. Based on the saved screen images, fixation and AOI files, the fixation plots were drawn. An eye fixation plot shows the scan paths of a subject’s eye movements during browsing and searching table data either in paper or

electronic PDF format. Eye fixation points were labeled by a sequence of numbers. The lines showed saccades from one fixation point to another.

### Search Patterns for Different Kinds of Tasks

Appendix 9 includes a full set of fixation plots (PDF) for the 8 questions in three task levels. For task level 1, as reflected on Figure 2, it is obvious that there are several areas of visual attention on the flat table file: column heading, row heading and area around the target answer. There were obvious back and forth eye movements between column headings and the target area, and between row headings and the target area.

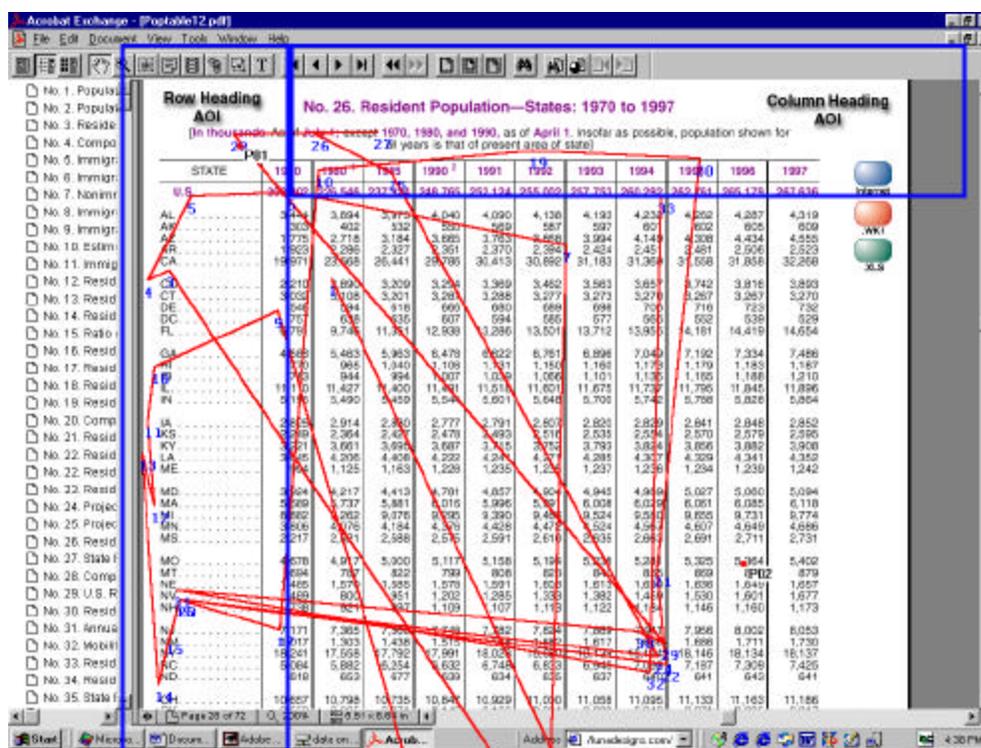


Figure 2. A fixation plot showing the scan paths and area of interests (AOI) for question 7 in PDF format (no scrolling).

For task level 2 – trend analysis question, Figure 3 shows eye movement pattern, which was similar to task level 1.

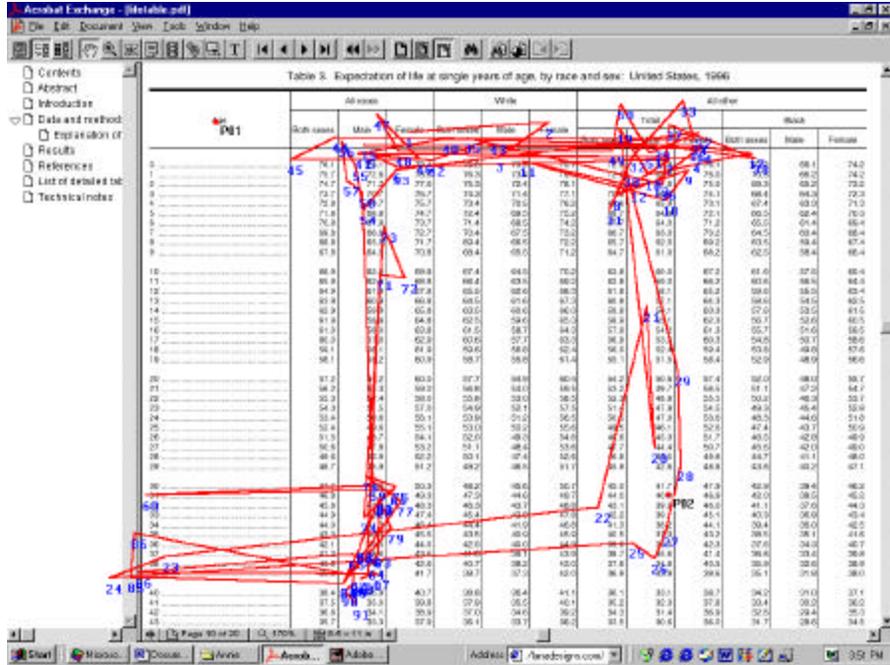


Figure 3. A fixation plot that shows the scan paths when the subject was searching the answer for question 2 in PDF format without scrolling.

For task level 3 - column comparison, Figure 4 shows a different search pattern, there were two columns of visual attention, connected by a series of back and forth saccades.

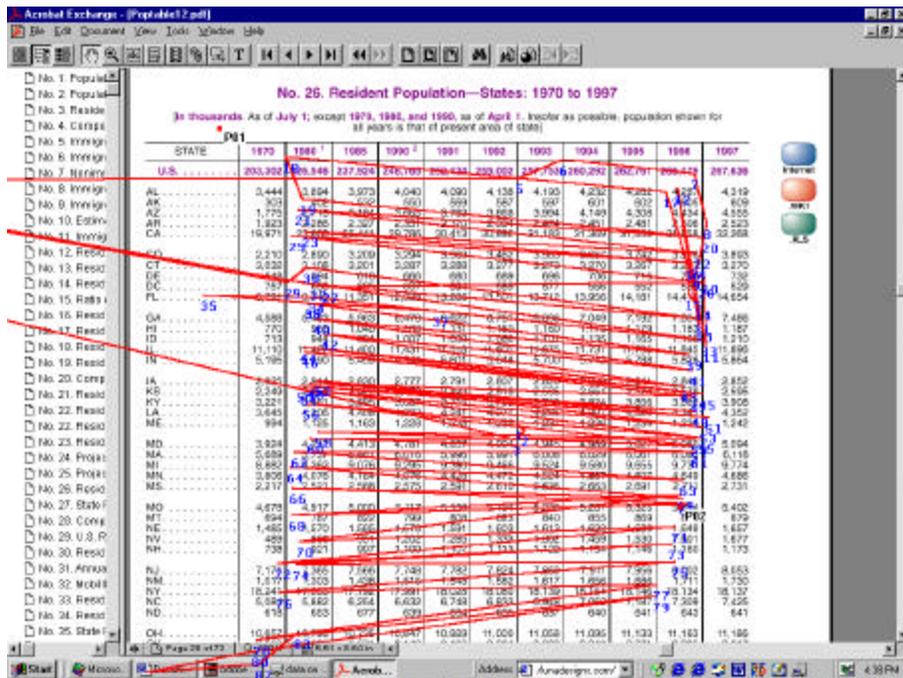
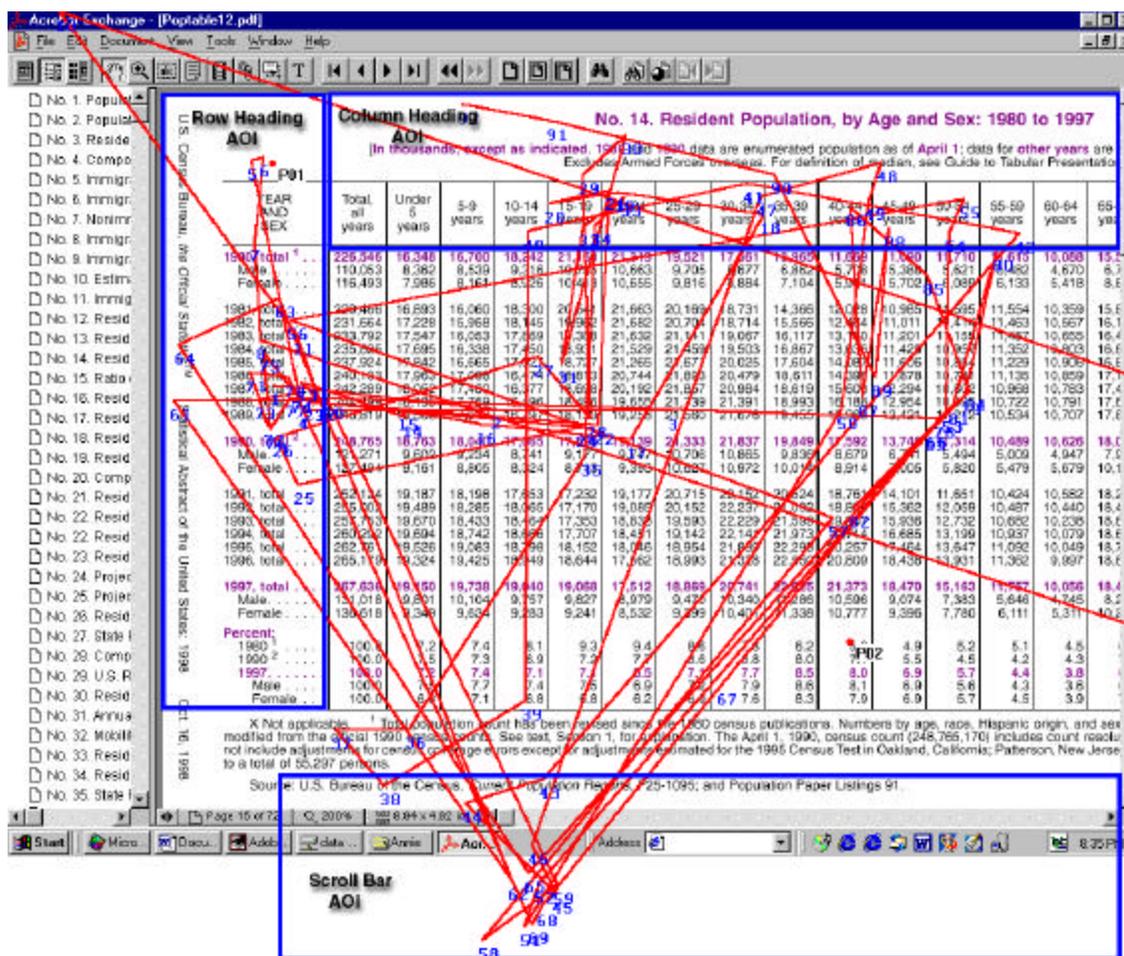


Figure 4. A fixation plot that shows the scan paths when the subject was searching the answer for question 8 in PDF format without scrolling.

### Scroll vs. Non-scroll

The answer for question 5 was 18 columns away from the row headings, which requires that the subjects' eyes move across the whole table to get the target answer. The Area Of Interests (AOIs) in Figure 5 includes: row heading, column heading and the scroll bar area. The AOIs are shown with dark borders in the plot.



Comparing Figure 5 and Figure 6, the differences between the two plots are obvious.

When the subject wanted to manipulate the PDF file, such as move the horizontal scroll bar, he had to pay extra attention to the scroll bar area at the bottom of the page. First he had to locate the scroll bar then adjust it. After he moved the horizontal bar to the right, the table's row heading might be invisible, therefore, he must go back using the scroll bar again. In this case, by analyzing the raw eye data using the EYENAL AOI Program and the Fixation Sequence Program, we know that the time the subject spent on the scroll bar area accounts for 9% of the total fixation duration. And the total number of eye fixations and total search time were greater and longer than for people who didn't use the scroll bar, respectively.

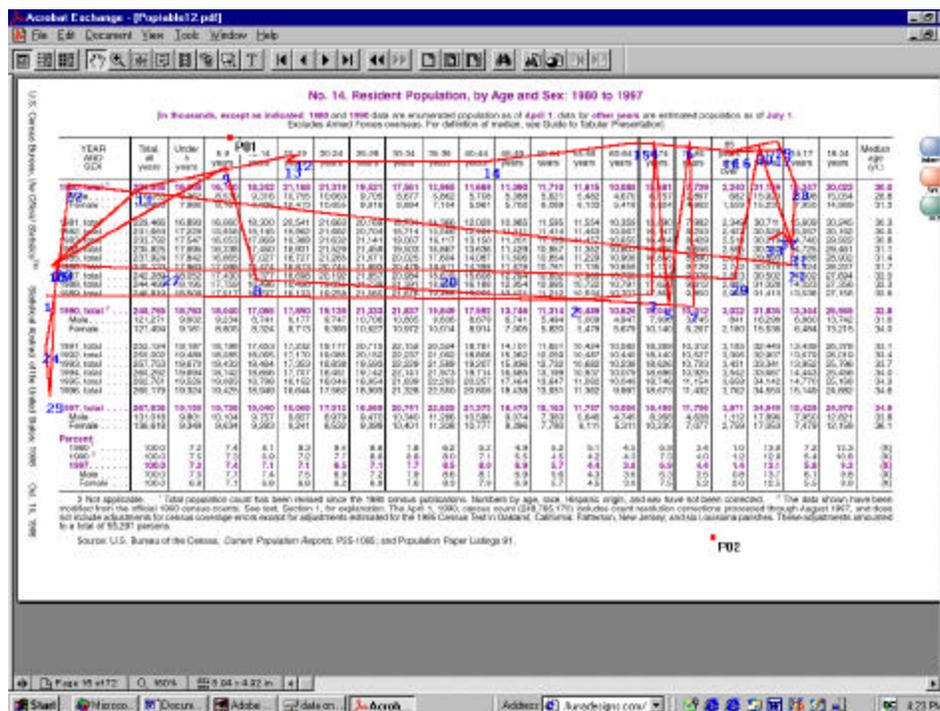


Figure 6. An example fixation plot that shows the scan paths for a subject answering question 5 in PDF format without scrolling.

### *Paper vs. PDF Format*

The two subjects tested in paper format were both experts, thus, the data generated by the two experts were compared only with the data collected from the other two experts who participated in the PDF test. Thus, there are no data on differences between nonexperts on paper and the PDF format.

As shown in Figure 7, 8, 9, without scrolling, there is no obvious difference between subjects who read table data in paper and PDF in terms of search time and the number of fixations; while, for mean fixation duration, as shown in Figure 9, paper format resulted in shorter mean fixation duration than PDF file. In a word, subjects who used the scroll bar when reading PDF tables showed different eye movement pattern and longer search time in comparison with those using paper format. No statistical tests of significance were computed due to the small sample size.

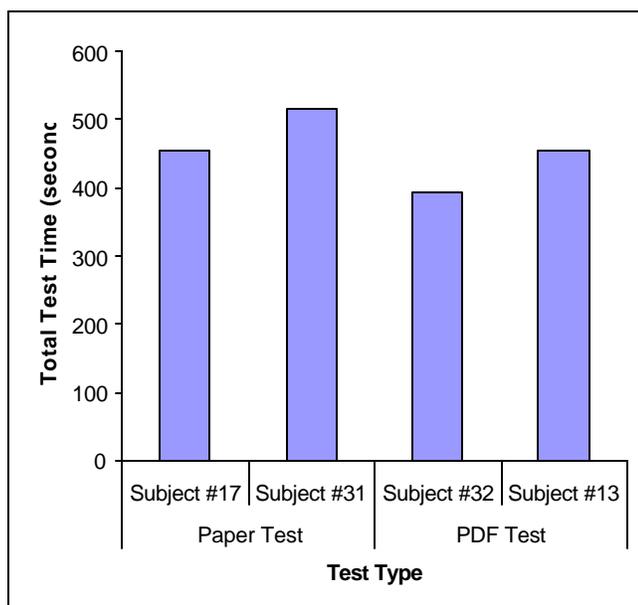


Figure 7. Total search time for the four experts, grouped by media type (paper vs. PDF).

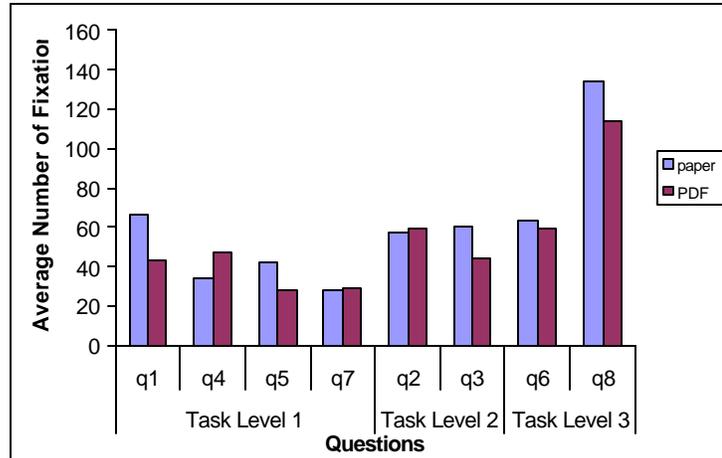


Figure 8. Average number of fixations for the four expert subjects, grouped by task levels.

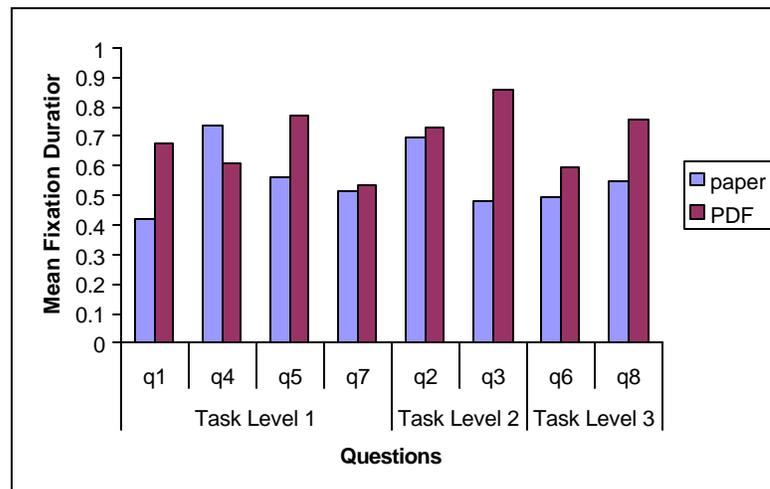


Figure 9. Mean fixation duration for the four expert subjects, grouped by task levels.

### *Total Search Time*

The total search time is the sum of search time for the 8 questions. Among these subjects, the first four subjects shown in the Figure 10 were statistically experienced (subject# 17, 31, 32 and 13). There is an obvious difference of total search time between experienced subjects and inexperienced subjects. The experienced subjects spent less time on searching than the inexperienced ones.

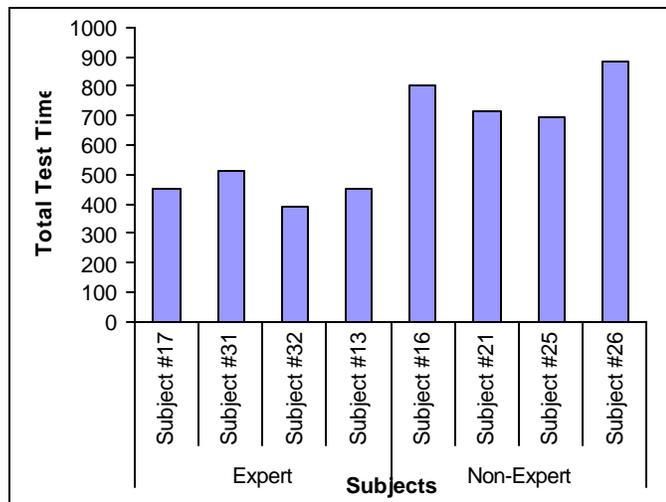


Figure 10. Total search time for the eight subjects, grouped by statistical experience level (expert vs. non-expert).

The data in Figure 10 were used as inputs to further analyze the differences between experts and non-experts based on average search time. Figure 11 shows the results. It is clear that experts spent much less time to finish all the search tasks.

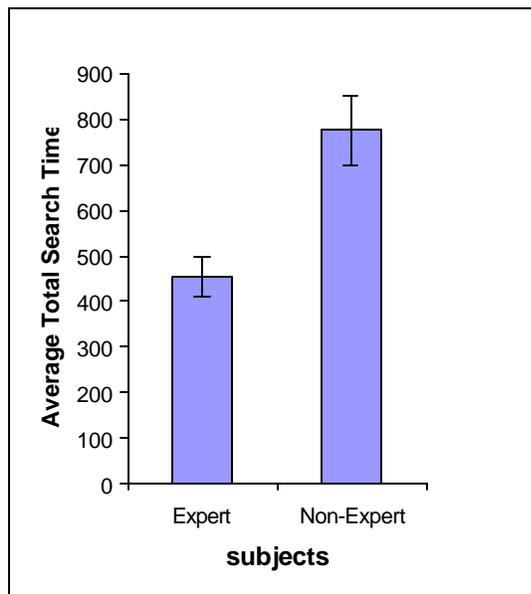


Figure 11. Average total search time for expert and non-expert. The vertical bar indicates the Standard Deviation.

Figure 12 displays the comparison of experts with non-experts with respect to average total search time. The difference between the two groups becomes bigger as the task level increases. This means that the more difficult the questions are, the more obvious the difference is. For task level 1, inexperienced subjects spent 23.6% more time than experienced subjects in searching. For task level 2, the number is bigger, 63.5% more time than experienced subjects in searching. As for task level 3, it is 135.1%.

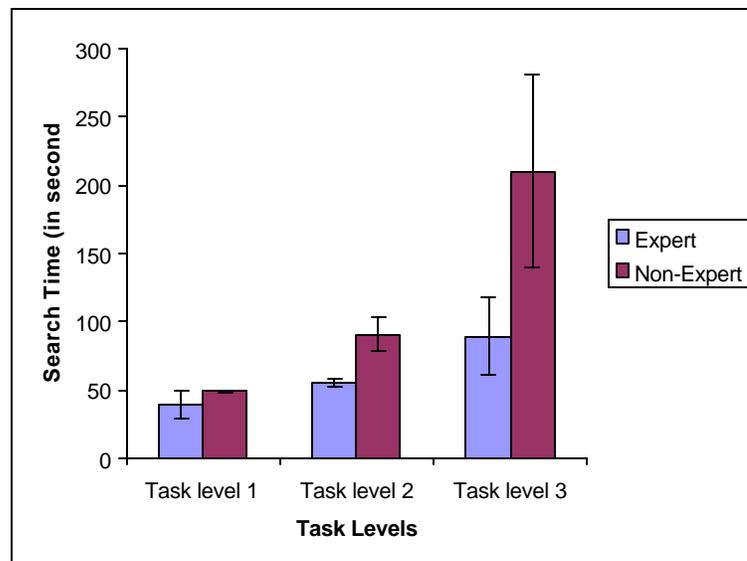


Figure 12. Mean search time for different tasks.

#### *Average Number of Fixations*

Likewise, the average number of fixations increases with task difficulty. Figure 13 shows that with the increase of task level (questions became more difficult), the average number of fixations become greater.

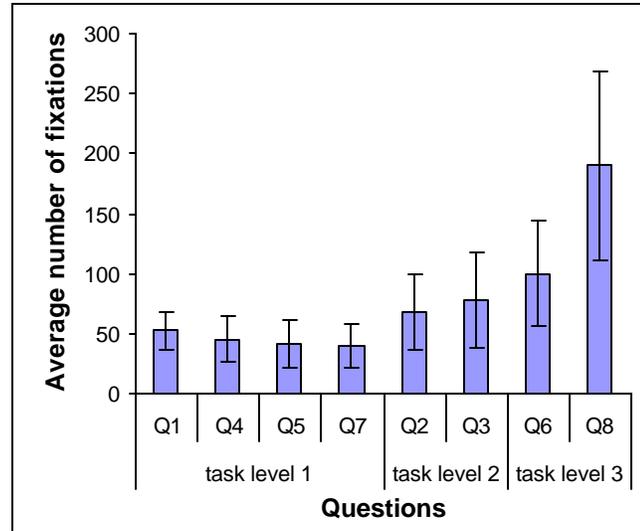


Figure 13. Average number of fixations for each question. \*

### *Mean Duration*

In this eye tracking study, a total of 6735 eye fixations were collected. Based on this eye fixation data, Figure 14 shows the mean fixation duration for the three tasks with the highest value for task level 2. Trend analysis requires comparison and simple calculation during the searching process, thus increasing the eye fixation duration.

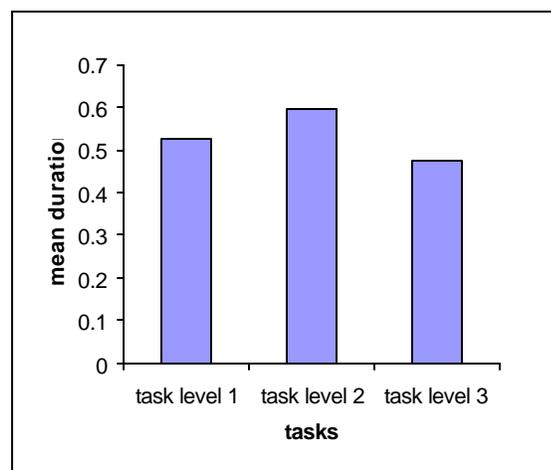


Figure 14. Mean fixation duration for tasks.

### *Table Headings*

As shown in Figure 15, for task level 1 and 2, in spite of table format (Paper/PDF), all subjects spent a relatively high percentage (39.4% - 49.9%) of the total fixation durations on reading table headings. Task 3 is not included in this analysis because of different search criteria. This result demonstrates the importance of headings in anchoring people in a data set.

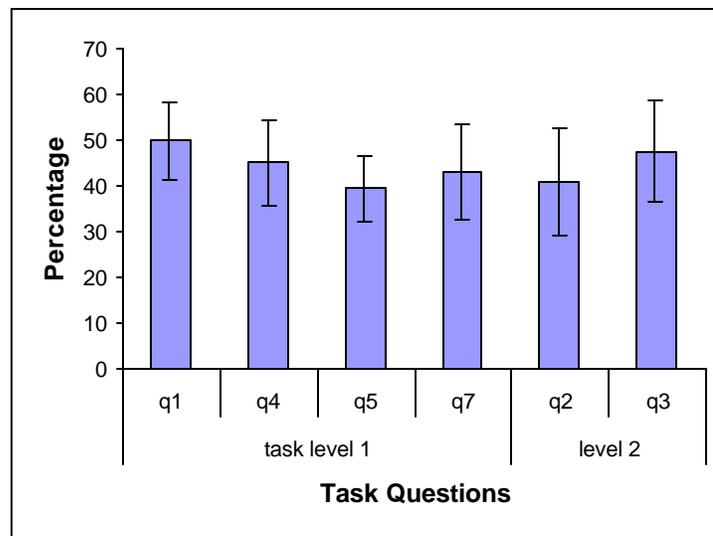


Figure 15. Percentage of mean total fixation duration on table headings (including column headings and row headings) for task level 1 and 2.

### NOTES:

\*: In Figure 13, subject #13 and #26 had two eye data segments for question 8. A very small part of eye data between the two segments were lost, thus, the average number of eye fixations for question 8 should be greater than what has been showed in the figure.

## CHAPTER 5: DISCUSSION AND RECOMMENDATIONS

Although the results of this study are interesting, we should be cautious in projecting the results to large populations because of the limitation of this eye-tracking study: the sample number is rather small, and the subjects were not randomly selected from the general population. Another problem is that eye-tracking itself is problematic, eye data is low-level data. To get a full understanding of e-tables we need to know not only the unconscious eye movements but also users' cognitive reflection and explanation of their information needs for processing, methods such as verbal expression (think aloud) were not used in this study. Additionally, in this study, tasks were limited using a fairly small selection of tables. Also subjects recruited were those who have interests in eye-tracking test, so the selection is artificial, the questions assigned to them did not reflect their real searching needs or interests.

The results show that statistical literacy and familiarity with tables can be an important factor in determining user's search performance with respect to table data. For a majority of questions, experts spent much less time on locating the target answers. For task level 1 (the most simple search), inexperienced subjects spent 23.6% more time than experienced subjects in searching. For task level 2 (the trend analysis search), inexperienced subjects took 63.5% more time than experienced subjects in searching. For task level 3 (footnote search and column comparison), it is 135.1%. This indicates that the difference between

expert and non-expert (as measured by if the subjects have taken a statistical course and their familiarity with tables) becomes more and more obvious as the task level increases.

Though it is reasonable to see most of the eye fixations are on the column headings, row headings and search areas, a surprising finding of this study is that table column and row headings caught an average of 44.3% of the visual attention (ranging from 39.4% to 49.9% for 8 questions as measured by eye fixation duration) of the whole search process, for both the experts and non-experts. Also the obvious back and forth eye movements indicate that people have to reference column or row headings from time to time when performing certain searching tasks. This result tells us that the importance of locating table headings during information-seeking process, it also suggests that locking the table headings, or highlighting the desired column or row could save time on searching table data.

According to the results of this study, the use of the scroll bar in PDF format, especially scrolling side to side using the horizontal scroll bar, resulted in longer search times, and poorer performance due to the fact that subjects had to locate the bar each time before moving it, which distracted their visual attention from the search question and disturbed their regular search pattern. Moreover, this led them into the trouble of losing column or row headings. In this case, since the screen repainting is slow, information could not be shown until scrolling stopped. In order to go back they had to wait until the screen reset had finished to begin to locate their position. Several subjects (including both experts and non-experts) had the same problems as stated above when using a big table in PDF

format. They prefer to use paper instead of PDF file for reading big tables. Most subjects felt it was OK to scroll up and down using the mouse wheel, but not the vertical scroll bar, because the scroll bar could lead to the jumping to another page, they would lose the whole table.

Only one test question required the subjects to look at the footnote. The feedback from subjects was that footnotes for a large table are hard to use for two reasons. First, the footnotes are not ordered clearly; second, accessibility is another issue since side-to-side scrolling also caused difficulties. For very long tables, scrolling down to find the footnote at the bottom was very inconvenient and slowed down search time.

According to these findings, we notice that the PDF file is not appropriate for browsing and searching in large tables because large tables contain more columns and rows than can be displayed on a single screen. Scrolling when using large tables can cause more subsequent problems, such as requiring the user to spend additional time on locating scroll bars, and the possibility of losing column or row headings. Without these headings, users will run into difficulties in identifying the meaning of a particular cell.

For some test questions in this study, it would have been helpful if people could sort the data to facilitate comparison. To get a better understanding of statistical tables, simple manipulation over quantitative data usually is required. For example, software such as Microsoft Excel enable users to manipulate and process data using functions like copy, paste and sort. As a matter of fact, large tables are complicated in both structures and

data relationships. Although usually a specific user is not interested in all the data in a table, the data in PDF or paper can not be used for further analysis, there is no way to extract and display only the information he/she cares about in such traditional flat table formats. This is especially a challenge for untrained users.

## CHAPTER 6: FUTURE STUDIES AND ACKNOWLEDGEMENT

### **Future Studies**

The study aimed to get some baseline knowledge about how people read online table data. Further eye-tracking studies will be carried out on how people read table data through specialized table browser interfaces. Hopefully, a clearer understanding of the human behavior on table browsing and searching will help us improve the table browser's interface design, and make table browsers better tools for citizens accessing and manipulating desired table data.

### **Acknowledgement**

The eye-tracking research described here was conducted at the Interaction Design Lab (IDL), School of Information and Library Science, UNC-CH. I want to thank my colleagues at the IDL, Dr. Gary Marchionini, Richard Spinks, and Laura Chessman, for their help with this research. This research project was supported by grant #9876640 from the National Science Foundation (NSF).

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## Appendix 1: AA-IRB Application

### Table Browser Interfaces: Eye-tracking Study

*Dr. Gary Marchionini*

#### **1. Project Description**

- a. The purpose of this research is to conduct eye-tracking studies on how people process tables, an ASL 504 eye-tracking system will be used to measure subjects' eye movement when they process table data.
- b. Participants will primarily include members of the UNC-CH community who are interested in participating in the eye-tracking study. Initially, participants will be given a brief questionnaire regarding their experience with both statistics and with statistical information seeking in online environments. A copy of this is in Appendix B. After the interview, participants will be asked to complete a series of tasks that involve finding information that is available in tables that are presented to the participants. The tasks will vary from simple information finding, to comparing and contrasting information, to basic analysis of information. Only a subset of tasks will be selected from the list of tasks in Appendix D. The participants will be presented with PDF files in flat table format. All instructions and tasks will be made available to the participants in a written format. Instructions will also be given verbally by the investigator. Responses to the tasks will be recorded by the eye-tracking system. The investigator will also take time measurements during completion of tasks by participants. The study will last approximately 1 hour.

#### **2. Participants**

- a. Participants will vary in age and gender. There will be approximately 10 participants.
- b. Participants will be selected based on statistical experience, both lack of and expertise in statistics.
- c. Participants will be recruited through fliers and list serve email messages.
- d. Participants will be provided with an inducement of \$25.

#### **3. Are participants at risk?**

Participants are not at risk. Eye-tracking equipment will be used in the study, it uses a camera positioned more than one foot from the subject to track eye movement and operates at a level at least an order of magnitude lower than what is considered to be safe.

#### **4. Minimizing Risk:**

Not applicable.

#### **5. Are illegal activities involved?**

Illegal activities are not involved.

**6. Is deception involved?**

Deception is not involved.

**7. What are the anticipated benefits to participants and/or society?**

The proposed empirical studies will lead to better understanding of how human process table data. A second benefit will be the development of effective and efficient user interfaces for processing table data.

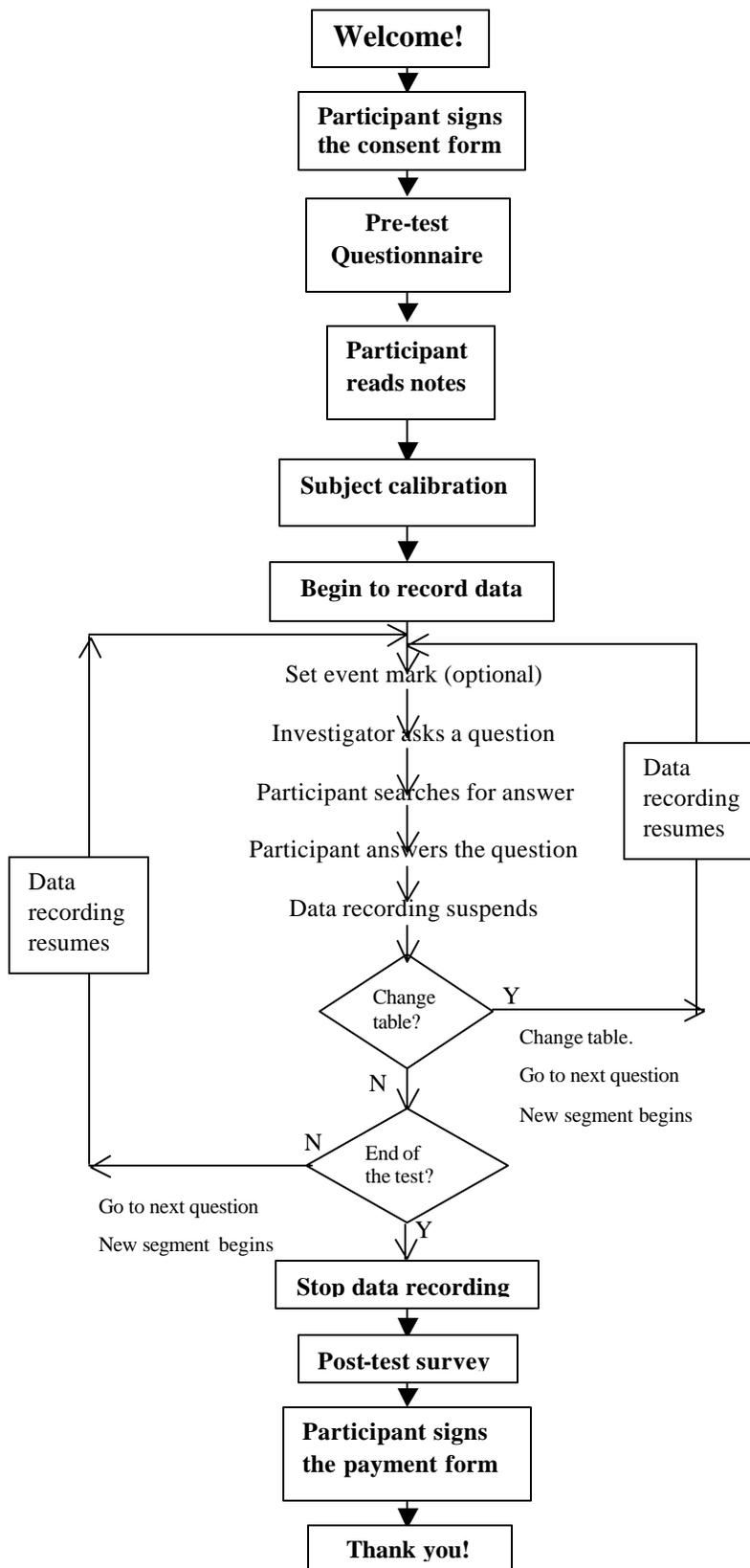
**8. How will prior consent be obtained?**

Participants will be presented a written informed consent form which they will be asked to sign. A copy of this is available in Appendix A.

**9. Describe security procedures for privacy and confidentiality.**

All transcripts and paperwork will be stored in a locked file cabinet at the School of Information and Library Science, not to be released. No information identifying a subject will be associated with the stored data. The subjects' privacy and confidentiality will be secure.

## Appendix 2: The Eye-Tracking Study Process Flow Chart



## Appendix 3: Consent Form for Table Browser Interfaces: Eye-tracking Study

### *Purpose of this Study*

We are inviting you to take part in a research study on how people process tables. We will conduct eye-tracking studies of online table usage. Dr. Gary Marchionini is the Principal Investigator of this research project.

### *The eye-tracking methods*

The pan/tilt optics module provided with the system is positioned more than one foot from your eyes. The module consists of an eye camera with a ring of near infrared LEDs around the lens opening. The LEDs emit an illumination beam that is trained on the retina; the optics module lens captures the light that is reflected back, resulting in a brightly lit image of the pupil. The optics module also captures the reflection of the illumination beam from the surface of the cornea - the corneal reflection. In addition, a magnetic head tracker is used in conjunction with the eye tracker to provide position data when the eyes are closed. The system measures the separation between the pupil and the corneal reflection and calculates the point of gaze.

### *Number of Participants*

There will be approximately 10 participants.

### *What Will Happen During the Study*

As a participant you will be asked questions regarding your experience with statistics and searching for statistical information in an electronic environment. After this you will be asked to complete a series of information finding and question answering tasks. To accomplish this you will be presented with PDF files in flat table format on a computer screen. The investigator will give you verbal instructions, and will ask you 8 questions one by one. During your searching, you can ask the investigator to repeat the question as often as you like. Once you have completed the tasks, the investigator will ask you a few questions regarding your experience with the tasks and your comments about the eye-tracking system.

### *Your Privacy is Important*

We will make every effort to protect your privacy. Any information obtained in the study will be recorded with a participant number, not your name. Since we will be making efforts to protect your privacy, we ask you to agree that we may use any information we get from this research study in any way we think is best for publication or education. If you have any questions regarding this study, please contact Dr. Gary Marchionini (966-3611, march@ils.unc.edu).

### *Risks and Discomforts*

You will not be subjected to risks other than those experienced in a traditional office situation. The eye-tracking equipment uses a camera positioned more than one foot from the subject to track eye movement and reflects infrared light at a level at least an order of magnitude lower than what is considered to be safe. The safe chronic ocular exposure

estimates for far-infrared exposure is 10 mW/sq.cm (David Sliney of US Army Environmental Hygiene Agency and Myron Worbarsht of Duke University Medical Center) and our ASL device uses between 0.1 and 0.3 mW/sq. cm on average. The head tracker receiver is positioned 12-24 inches from the transmitter that produces a magnetic field between one-eighth and one-quarter (depending on head position) of the normal earth field of 0.6 gauss (manufacturer specifications). This configuration of eye and head tracker supplied by ASL Laboratories has found wide applications in government, university, and corporate laboratories.

*Your Rights*

You will be paid \$25 for your participation in the eye-tracking study, which should last approximately 1 hour. You are free to refuse to participate or to withdraw from the study at any time without penalty and without jeopardy. You will be paid for the time you have completed.

*Institutional Review Board Approval*

The Academic Affairs Institutional Review Board (AA-IRB) of the University of North Carolina at Chapel Hill has approved this study. If you have any concerns about your rights in this study you may contact the Chair of the AA-IRB:

David A. Eckerman, Chair  
CB# 4100, 201 Bynum Hall  
UNC-CH  
Chapel Hill, NC 27599-4100  
962-7761  
aa-irb@unc.edu

I have had the chance to ask any questions I have about this study, and they have been answered for me.

I have read the information in this consent form, and I agree to be in the study. I understand I will get a copy of this consent form after I sign it.

---

(Signature of Participant)

---

(DATE)

## Appendix 4: Pre-test Demographic Questionnaire

Your answers to the following questions will help the study researchers to analyze the test results.

Participant ID \_\_\_\_\_

Age \_\_\_\_\_ Gender Male \_\_\_\_\_  
Female \_\_\_\_\_

Do you wear glasses or contacts? Yes \_\_\_\_\_  
No \_\_\_\_\_

To control for different levels of computer/software and statistical literacy, please help us with the following information:

1. How often do you use a computer?

Never      Occasionally      Monthly      Weekly      Daily

2. What applications do you use? (Please check all that apply)

Email      Word Processing      Web Surfing      Games  
Database      Multimedia      Programming

3. Have you ever taken a statistical course?

Yes      No

If yes, when did you take it, choose all that apply:

High School      College      Graduate Study      Professional Training

4. Please select any statistical software package(s) you have used:

Excel or other spread sheet      SAS      SPSS      Others

We'd like to know how often you use statistical tables. Please check the response that best represents your experience.

5. Please tell us how many times you have used the following tables (including both paper and electronic formats):

Stock market tables/listings

None	1 - 5	6 - 15	>15
------	-------	--------	-----

Time schedule tables (e.g. bus, airline, class schedule)

None	1 - 5	6 - 15	>15
------	-------	--------	-----

Consumer information tables (e.g. cost comparison tables)

None	1 - 5	6 - 15	>15
------	-------	--------	-----

Nutritional labels (e.g. cereal box)

None	1 - 5	6 - 15	>15
------	-------	--------	-----

Research results in articles

None	1 - 5	6 - 15	>15
------	-------	--------	-----

Government statistics on the Web (e.g. health, demographic tables)

None	1 - 5	6 - 15	>15
------	-------	--------	-----

Tax tables

None	1 - 5	6 - 15	>15
------	-------	--------	-----

6. Have you used Fedstats ([www.fedstats.gov](http://www.fedstats.gov))?

Yes      No

7. How often have you used data in tables from government Web sites?

Never      Occasionally      Monthly      Weekly      Daily

8. How often have you used statistical tables on the Web?

Never      Occasionally      Monthly      Weekly      Daily

## Appendix 5: Notes for Paper Test

Before we begin data collection, consider the following:

1. Please don't move the chair, adjust your body position in the chair so that you feel comfortable. Although it's not necessary that you remain absolutely still, please don't move your head too much.
2. Get familiar with the table the layout and other general information.
3. Most of the questions are directly related to table data, some questions need simple comparison or analysis; one or two questions may need you to pay attention to the table footnote.
4. There are a total 8 questions. The investigator will ask you questions one by one. During your searching, you can ask the investigator to repeat the question as often as you like. When you find the answer, please say it directly.
5. Please don't point to the screen using your finger, because this will prevent the optics module from working properly.

Thank you very much for your cooperation!!

## Appendix 6: Notes for PDF Test

Before we begin data collection, consider the following:

1. Please don't move the chair, adjust your body position in the chair so that you feel comfortable. Although it's not necessary that you remain absolutely still, please don't move your head too much.
2. Get familiar with the table layout and other general information on tables in electronic PDF format. Please use the wheel on the mouse to scroll up and down instead of the scroll bar during the session. Use the table of contents on the left side of the screen to select a table; use the "window" menu on the menu bar to toggle from the life tables to population tables.
3. Most of the questions are directly related to table data, some questions need simple comparison or analysis; one or two questions may need you to pay attention to the table footnote.
4. There are a total 8 questions. The investigator will ask you questions one by one. During your searching, you can ask the investigator to repeat the question as often as you like. When you find the answer, please say it directly.
5. Please don't point to the screen using your finger, because this will prevent the optics module from working properly.

Thank you very much for your cooperation!!

## Appendix 7: Questions

Start time:

1. (Life table #3) In 1996 how many more years was a 50-year-old (or 40-year-old) woman expected to live?
2. (Life table #3) Across all groups, what happens to the difference in life expectancy between males and females as people age?
3. (Life table #5) What happened to the difference in age expectancy of males and females between 1900 and 1996?
4. (Population table #14) In 1997 what was the resident population of all females?
5. (Population table #14) In 1988 what was the resident population of the 15-19 (or 14-17) years age group?
6. (Population table #14) In 1990, by what amount in the total population has the data been adjusted?
7. (Population table #26) What was the population of Utah (or New Jersey) in 1994?
8. (Population table #26) Compared to the population information from 1997, which two states have decreased in population size since 1970?

End time:

## Appendix 8: Post-Tasks Survey

1. Is this test your first experience with eye tracking, how do feel about it?
2. Did you have any problems using the tables?
3. What suggestions could you give us to improve the performance of the eye-tracking study?
4. What suggestions could you give us to improve reading tables online?

# Appendix 9: An Example Set of Fixation Plots (PDF)

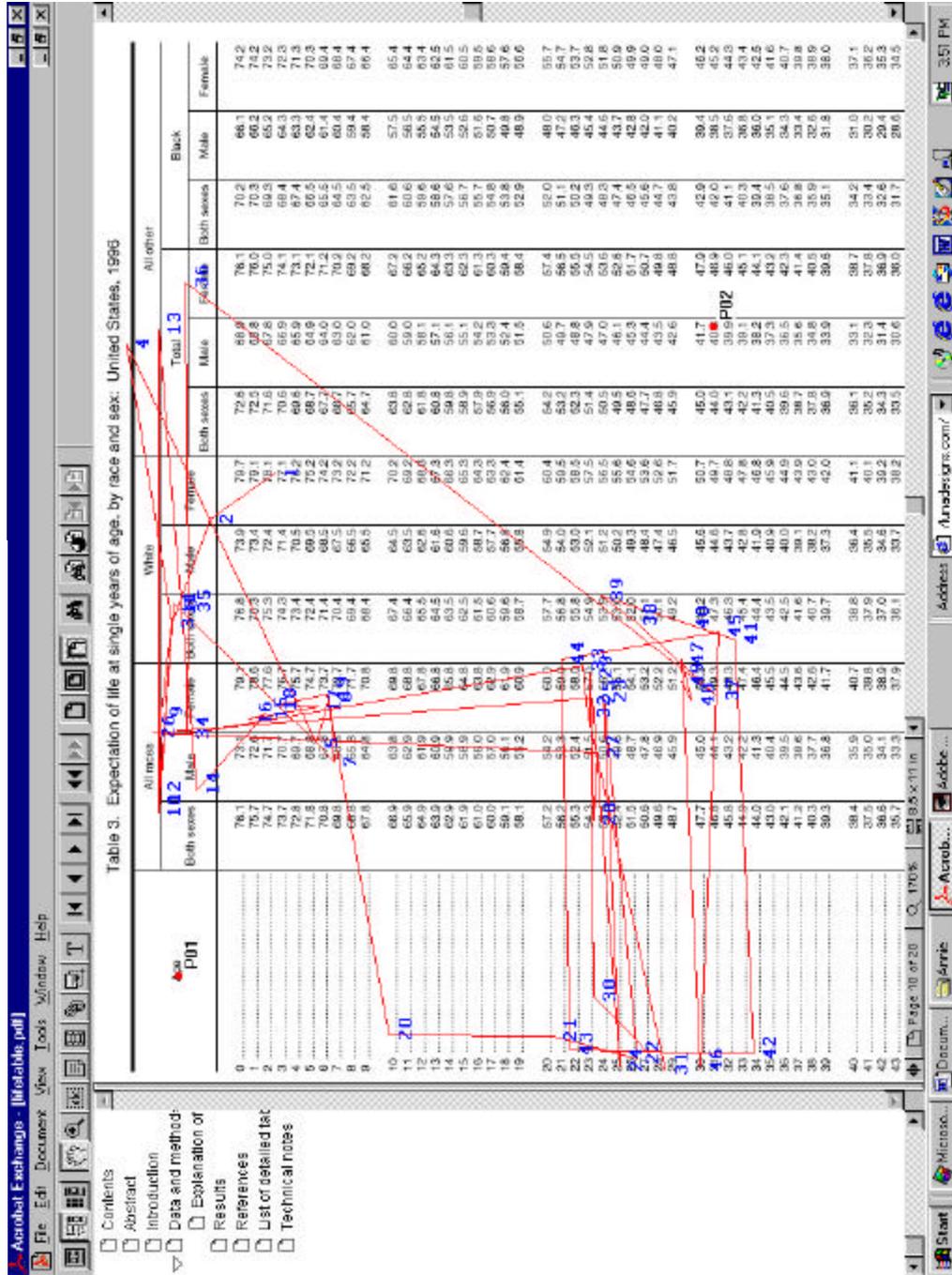


Figure 16. Fixplot for question 1

Table 3. Expectation of life at single years of age, by race and sex: United States, 1996

Age	All races						White						All other								
	Both sexes			Female			Male			Female			Male			Female			Male		
	Both sexes	Male	Female																		
0	76.1	73.1	79.9	76.8	73.9	79.7	76.1	73.2	79.1	76.1	73.2	79.1	76.1	73.2	79.1	76.1	73.2	79.1	76.1	73.2	79.1
1	75.7	72.6	78.6	76.3	73.4	79.1	75.7	72.6	78.6	76.3	73.4	79.1	75.7	72.6	78.6	76.3	73.4	79.1	75.7	72.6	78.6
2	74.7	71.7	77.6	75.3	72.4	78.1	74.7	71.6	77.1	75.3	72.4	78.1	74.7	71.6	77.1	75.3	72.4	78.1	74.7	71.6	77.1
3	73.7	70.7	76.6	74.3	71.4	77.1	73.7	70.6	76.1	74.3	71.4	77.1	73.7	70.6	76.1	74.3	71.4	77.1	73.7	70.6	76.1
4	72.9	69.7	75.7	73.4	70.5	76.2	72.9	69.6	75.2	73.4	70.5	76.2	72.9	69.5	75.1	73.4	70.4	76.1	72.9	69.5	75.1
5	71.8	68.5	74.6	72.3	69.4	75.1	71.8	68.4	74.1	72.3	69.3	75.1	71.8	68.3	74.0	72.3	69.2	75.0	71.8	68.2	74.0
6	70.8	67.5	73.7	71.4	68.5	74.2	70.8	67.4	73.2	71.4	68.4	74.2	70.8	67.3	73.1	71.4	68.3	74.1	70.8	67.2	73.0
7	69.8	66.5	72.7	70.4	67.5	73.2	69.8	66.4	72.2	70.4	67.4	73.2	69.8	66.3	72.1	70.4	67.3	73.1	69.8	66.2	72.9
8	68.8	65.6	71.7	69.4	66.5	72.2	68.8	65.5	71.2	69.4	66.4	72.2	68.8	65.4	71.1	69.4	66.3	72.1	68.8	65.4	71.9
9	67.8	64.6	70.8	68.4	65.5	71.2	67.8	64.5	70.2	68.4	65.4	71.2	67.8	64.4	70.2	68.4	65.3	71.1	67.8	64.3	70.9
10	66.9	63.8	69.8	67.2	64.5	70.2	66.9	63.7	69.2	67.2	64.4	70.2	66.9	63.6	69.2	67.2	64.3	69.2	66.8	63.6	69.1
11	65.9	62.9	68.8	66.4	63.6	69.2	65.9	62.8	68.2	66.4	63.5	69.2	65.9	62.7	68.2	66.4	63.5	69.1	65.8	62.5	68.1
12	64.9	61.9	67.8	65.0	62.6	68.2	64.9	61.8	67.2	65.0	62.5	68.2	64.9	61.7	67.2	65.0	62.4	68.1	64.8	61.6	67.1
13	63.9	60.9	66.8	64.1	61.6	67.2	63.9	60.8	66.2	64.1	61.5	67.2	63.9	60.7	66.2	64.0	61.5	67.1	63.8	60.5	66.1
14	62.9	59.9	65.8	63.2	60.6	66.2	62.9	59.8	65.2	63.2	60.5	66.2	62.9	59.7	65.2	63.1	60.4	66.1	62.8	59.4	65.1
15	61.9	58.9	64.8	62.2	59.6	65.2	61.9	58.7	64.2	62.2	59.5	65.2	61.9	58.6	64.2	62.1	59.3	65.1	61.8	58.3	64.1
16	61.0	58.0	63.8	61.3	58.7	64.2	61.0	57.9	63.2	61.3	58.6	64.2	61.0	57.8	63.2	61.2	58.2	64.1	60.9	57.2	63.1
17	60.0	57.0	62.8	60.3	57.7	63.2	60.0	56.9	62.2	60.3	57.6	63.2	60.0	56.8	62.2	60.2	57.1	63.1	59.9	56.1	62.1
18	59.1	56.1	61.8	59.4	56.6	62.2	59.1	56.0	61.2	59.4	56.5	62.2	59.1	55.9	61.2	59.3	56.0	62.1	59.8	55.0	61.1
19	58.2	55.2	60.8	58.7	55.8	61.2	58.2	55.1	60.2	58.7	55.7	61.2	58.2	55.0	60.2	58.7	55.6	61.1	58.1	54.1	60.1
20	57.3	54.3	59.8	57.8	54.9	60.2	57.3	54.2	59.2	57.8	54.8	60.2	57.3	54.1	59.2	57.8	54.7	60.1	57.0	53.1	59.1
21	56.4	53.4	58.8	56.9	54.0	59.2	56.4	53.1	58.2	56.9	53.9	59.2	56.4	53.0	58.2	56.9	53.8	59.1	56.3	52.1	58.1
22	55.5	52.5	57.8	56.0	53.1	58.2	55.5	52.0	57.2	56.0	52.9	58.2	55.5	51.9	57.2	56.0	52.8	59.0	55.4	51.0	57.1
23	54.6	51.6	56.8	55.1	52.2	57.2	54.6	51.1	56.2	55.1	52.1	57.2	54.6	51.0	56.2	55.0	51.9	58.9	54.5	50.1	56.1
24	53.7	50.7	55.8	54.2	51.3	56.2	53.7	50.2	55.2	54.2	51.2	56.2	53.7	50.1	55.2	54.1	51.0	58.8	53.6	49.2	55.1
25	52.8	49.8	54.8	53.3	50.4	55.2	52.8	49.3	54.2	53.3	50.3	55.2	52.8	49.2	54.2	53.1	50.0	58.7	52.7	48.3	54.1
26	51.9	48.9	53.8	52.4	49.5	54.2	51.9	48.4	53.2	52.4	49.4	54.2	51.9	48.3	53.2	52.0	49.1	58.6	51.8	47.4	53.1
27	51.0	48.0	52.8	51.5	48.6	53.2	51.0	47.5	52.2	51.5	48.5	53.2	51.0	47.4	52.2	51.1	48.0	58.5	50.9	46.5	52.1
28	50.1	47.1	51.8	50.6	47.7	52.2	50.1	46.6	51.2	50.6	47.8	52.2	50.1	46.5	51.2	50.0	46.9	58.4	50.0	45.6	51.1
29	49.2	46.2	50.8	49.7	46.8	51.2	49.2	45.9	50.2	49.7	46.9	51.2	49.2	45.8	50.2	49.1	46.0	58.3	49.1	44.7	50.1
30	48.3	45.3	49.8	48.8	45.9	50.2	48.3	45.0	49.2	48.8	45.9	50.2	48.3	44.9	49.2	48.0	45.1	58.2	48.0	43.8	49.1
31	47.4	44.4	48.8	47.9	45.0	49.2	47.4	44.1	48.2	47.9	45.0	49.2	47.4	44.0	48.2	47.0	44.0	58.1	47.0	42.9	48.1
32	46.5	43.5	47.8	47.0	44.1	48.2	46.5	43.2	47.2	47.0	44.0	48.2	46.5	43.1	47.2	46.0	43.0	58.0	46.0	42.0	47.1
33	45.6	42.6	46.8	46.1	43.2	47.2	45.6	42.3	46.2	46.1	43.1	47.2	45.6	42.2	46.2	45.0	42.0	57.9	45.0	41.1	46.1
34	44.7	41.7	45.8	45.2	42.3	46.2	44.7	41.4	45.2	45.2	42.2	46.2	44.7	41.3	45.2	44.0	41.0	57.8	44.0	40.2	45.1
35	43.8	40.8	44.8	44.5	41.4	45.2	43.8	40.5	44.2	44.5	41.3	45.2	43.8	40.4	44.2	43.0	40.0	57.7	43.0	39.3	44.1
36	42.9	39.9	43.8	43.8	40.5	44.2	42.9	39.6	43.2	43.8	40.4	44.2	42.9	39.5	43.2	42.0	39.0	57.6	42.0	38.4	43.1
37	42.0	38.0	42.8	42.9	39.6	43.2	42.0	38.7	42.2	42.9	39.5	43.2	42.0	38.6	42.2	41.0	38.0	57.5	41.0	37.5	42.1
38	41.1	37.1	41.8	42.0	38.7	42.2	41.1	37.8	41.2	42.0	38.6	42.2	41.1	37.7	41.2	40.0	37.0	57.4	40.0	36.6	41.1
39	40.2	36.2	40.8	41.1	37.8	41.2	40.2	36.9	40.2	41.1	37.7	41.2	40.2	36.8	40.2	39.0	36.0	57.3	39.0	35.7	40.1
40	39.3	35.3	39.8	40.2	36.9	40.2	39.3	36.0	39.2	40.2	36.6	40.2	39.3	35.9	39.2	38.0	35.0	57.2	38.0	34.8	39.1
41	38.4	34.4	38.8	39.1	36.0	39.2	38.4	35.1	38.2	39.1	36.0	39.2	38.4	35.0	38.2	37.0	34.0	57.1	37.0	33.9	38.1
42	37.5	33.5	37.8	38.0	35.1	38.2	37.5	34.2	37.2	38.0	35.0	38.2	37.5	34.1	37.2	36.0	33.0	57.0	36.0	33.0	37.1
43	36.6	32.6	36.8	37.1	34.2	37.2	36.6	33.3	36.2	37.1	34.1	37.2	36.6	33.2	36.2	35.0	32.0	56.9	35.0	32.0	36.1
44	35.7	31.7	35.8	36.2	33.3	36.2	35.7	32.4	35.2	36.2	33.2	36.2	35.7	32.3	35.2	34.0	31.0	56.8	34.0	31.0	35.1
45	34.8	30.8	34.8	35.3	32.4	35.2	34.8	31.5	34.2	35.3	32.3	35.2	34.8	31.4	34.2	33.0	30.0	56.7	33.0	30.0	34.1
46	33.9	29.9	33.8	34.4	31.5	34.2	33.9	30.6	33.2	34.4	31.4	34.2	33.9	30.5	33.2	32.0	29.0	56.6	32.0	29.0	33.1
47	33.0	29.0	32.8	33.5	30.6	33.2	33.0	29.7	32.2	33.5	30.5	33.2	33.0	29.6	32.2	31.0	28.0	56.5	31.0	28.0	32.1
48	32.1	28.1	31.8	32.6	29.7	32.2	32.1	28.8	31.2	32.6	29.6	32.2	32.1	28.7	31.2	30.0	27.0	56.4	30.0	27.0	31.1
49	31.2	27.2	30.8	31.7	28.8	31.2	31.2	27.9	30.2	31.7	28.7	31.2	31.2	27.8	30.2	29.0	26.0	56.3	29.0	26.0	30.1
50	30.3	26.3	29.8	30.8	27.9	30.2	30.3	27.0	29.2	30.8	27.8	30.2	30.3	26.9	29.2	28.0	25.0	56.2	28.0	25.0	29.1
51	29.4	25.4	28.8	29.9	27.0	29.2	29.4	26.1	28.2	29.9	26.9	29.2	29.4	26.0	28.2	27.0	24.0	56.1	27.0	24.0	28.1
52	28.5	24.5	27.8	29.0	26.1	28.2	28.5	25.2	27.2	29.0	26.0	28.2	28.5	25.1	27.2	26.0	23.0	56.0	26.0	23.0	27.1
53	27.6	23.6	26.8	28.1	25.2	27.2	27.6	24.3	26.2	28.1	25.1	27.2	27.6	24.2	26.2	25.0	22.0	55.9	25.0	22.0	26.1
54	26.7	22.7	25.8	27.2	24.3	26.2	26.7	23.4	25.2	27.2	24.2	26.2	26.7	23.3	25.2	24.0	21.0	55.8	24.0	21.0	25.1
55	25.8	21.8	24.8	26.3	23.4	25.2	25.8	22.5	24.2	26.3	23.3	25.2	25.8	22.4	24.2	23.0	20.0	55.7	23.0	20.0	24.1
56	24.9	20.9	23.8	25.4	22.5	24.2	24.9	21.6	23.2	25.4	22.4	24.2	24.9	21.5	23.2	22.0	19.0	55.6	22.0	19.0	23.1
57	24.0	20.0	22.8	24.5	21.6	23.2	24.0	20.7	22.2	24.5	21.5	23.2	24.0	20.6	22.2	21.0	18.0	55.5	21.0	18.0	22.1
58	23.1	19.1	21.8	23.6	20.7	22.2	23.1	19.8	21.2	23.6	20.6	22.2	23.1	19.7	21.2	20.0	17.0	55.4	20.0	17.0	21.1
59	22.2	18.2	20.8	22.7	19.8	21.2	22.2	18.9	20.2	22.7	19.7	21.2	22.2	18.8	20.2	19.0	16.0	55.			

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Table 5. Estimated average length of life in years, by race and sex: Death-registration States, 1900-28, and United States, 1929-96

[For selected years, life table values shown are estimates; see Technical notes. Beginning 1970 excludes deaths of nonresidents of the United States; see Technical notes]

Area and year	All races						White						All other												
	Both sexes			Female			Both sexes			Male			Female			Both sexes			Male			Female			
	Both sexes	Male	Female																						
UNITED STATES 1	76.1	73.1	79.1	76.8	73.9	79.7	72.6	71.9	73.6	79.7	72.6	71.9	73.6	79.7	72.6	71.9	73.6	79.7	72.6	71.9	73.6	79.7	72.6	71.9	73.6
1900	76.1	73.1	79.1	76.8	73.9	79.7	72.6	71.9	73.6	79.7	72.6	71.9	73.6	79.7	72.6	71.9	73.6	79.7	72.6	71.9	73.6	79.7	72.6	71.9	73.6
1901	75.8	72.8	78.9	76.5	73.4	79.6	71.9	70.9	72.9	78.9	71.9	70.9	72.9	78.9	71.9	70.9	72.9	78.9	71.9	70.9	72.9	78.9	71.9	70.9	72.9
1902	75.5	72.5	78.8	76.3	73.1	79.5	71.7	70.7	72.7	78.8	71.7	70.7	72.7	78.8	71.7	70.7	72.7	78.8	71.7	70.7	72.7	78.8	71.7	70.7	72.7
1903	75.2	72.2	78.7	76.0	72.9	79.4	71.5	70.5	72.5	78.7	71.5	70.5	72.5	78.7	71.5	70.5	72.5	78.7	71.5	70.5	72.5	78.7	71.5	70.5	72.5
1904	75.0	72.0	78.6	75.8	72.7	79.3	71.3	70.3	72.3	78.6	71.3	70.3	72.3	78.6	71.3	70.3	72.3	78.6	71.3	70.3	72.3	78.6	71.3	70.3	72.3
1905	74.8	71.8	78.5	75.6	72.5	79.2	71.1	70.1	72.1	78.5	71.1	70.1	72.1	78.5	71.1	70.1	72.1	78.5	71.1	70.1	72.1	78.5	71.1	70.1	72.1
1906	74.6	71.6	78.4	75.4	72.4	79.1	70.9	70.0	72.0	78.4	70.9	70.0	72.0	78.4	70.9	70.0	72.0	78.4	70.9	70.0	72.0	78.4	70.9	70.0	72.0
1907	74.4	71.4	78.3	75.2	72.2	79.0	70.7	69.9	71.9	78.3	70.7	69.9	71.9	78.3	70.7	69.9	71.9	78.3	70.7	69.9	71.9	78.3	70.7	69.9	71.9
1908	74.2	71.2	78.2	75.0	72.0	78.9	70.5	69.7	71.8	78.2	70.5	69.7	71.8	78.2	70.5	69.7	71.8	78.2	70.5	69.7	71.8	78.2	70.5	69.7	71.8
1909	74.0	71.0	78.1	74.8	71.8	78.8	70.3	69.5	71.7	78.1	70.3	69.5	71.7	78.1	70.3	69.5	71.7	78.1	70.3	69.5	71.7	78.1	70.3	69.5	71.7
1910	73.8	70.8	78.0	74.6	71.6	78.7	70.1	69.3	71.6	78.0	70.1	69.3	71.6	78.0	70.1	69.3	71.6	78.0	70.1	69.3	71.6	78.0	70.1	69.3	71.6
1911	73.6	70.6	77.9	74.4	71.4	78.6	69.9	69.1	71.5	77.9	69.9	69.1	71.5	77.9	69.9	69.1	71.5	77.9	69.9	69.1	71.5	77.9	69.9	69.1	71.5
1912	73.4	70.4	77.8	74.2	71.2	78.5	69.7	68.9	71.4	77.8	69.7	68.9	71.4	77.8	69.7	68.9	71.4	77.8	69.7	68.9	71.4	77.8	69.7	68.9	71.4
1913	73.2	70.2	77.7	74.0	71.0	78.4	69.5	68.7	71.3	77.7	69.5	68.7	71.3	77.7	69.5	68.7	71.3	77.7	69.5	68.7	71.3	77.7	69.5	68.7	71.3
1914	73.0	70.0	77.6	73.8	70.8	78.3	69.3	68.5	71.2	77.6	69.3	68.5	71.2	77.6	69.3	68.5	71.2	77.6	69.3	68.5	71.2	77.6	69.3	68.5	71.2
1915	72.8	69.8	77.5	73.6	70.6	78.2	69.1	68.3	71.1	77.5	69.1	68.3	71.1	77.5	69.1	68.3	71.1	77.5	69.1	68.3	71.1	77.5	69.1	68.3	71.1
1916	72.6	69.6	77.4	73.4	70.4	78.1	68.9	68.1	71.0	77.4	68.9	68.1	71.0	77.4	68.9	68.1	71.0	77.4	68.9	68.1	71.0	77.4	68.9	68.1	71.0
1917	72.4	69.4	77.3	73.2	70.2	78.0	68.7	67.9	70.9	77.3	68.7	67.9	70.9	77.3	68.7	67.9	70.9	77.3	68.7	67.9	70.9	77.3	68.7	67.9	70.9
1918	72.2	69.2	77.2	73.0	70.0	77.9	68.5	67.7	70.8	77.2	68.5	67.7	70.8	77.2	68.5	67.7	70.8	77.2	68.5	67.7	70.8	77.2	68.5	67.7	70.8
1919	72.0	69.0	77.1	72.8	69.8	77.8	68.3	67.5	70.7	77.1	68.3	67.5	70.7	77.1	68.3	67.5	70.7	77.1	68.3	67.5	70.7	77.1	68.3	67.5	70.7
1920	71.8	68.8	77.0	72.6	69.6	77.7	68.1	67.3	70.6	77.0	68.1	67.3	70.6	77.0	68.1	67.3	70.6	77.0	68.1	67.3	70.6	77.0	68.1	67.3	70.6
1921	71.6	68.6	76.9	72.4	69.4	77.6	67.9	67.1	70.5	76.9	67.9	67.1	70.5	76.9	67.9	67.1	70.5	76.9	67.9	67.1	70.5	76.9	67.9	67.1	70.5
1922	71.4	68.4	76.8	72.2	69.2	77.5	67.7	66.9	70.4	76.8	67.7	66.9	70.4	76.8	67.7	66.9	70.4	76.8	67.7	66.9	70.4	76.8	67.7	66.9	70.4
1923	71.2	68.2	76.7	72.0	69.0	77.4	67.5	66.7	70.3	76.7	67.5	66.7	70.3	76.7	67.5	66.7	70.3	76.7	67.5	66.7	70.3	76.7	67.5	66.7	70.3
1924	71.0	68.0	76.6	71.8	68.8	77.3	67.3	66.5	70.2	76.6	67.3	66.5	70.2	76.6	67.3	66.5	70.2	76.6	67.3	66.5	70.2	76.6	67.3	66.5	70.2
1925	70.8	67.8	76.5	71.6	68.6	77.2	67.1	66.3	70.1	76.5	67.1	66.3	70.1	76.5	67.1	66.3	70.1	76.5	67.1	66.3	70.1	76.5	67.1	66.3	70.1
1926	70.6	67.6	76.4	71.4	68.4	77.1	66.9	66.1	70.0	76.4	66.9	66.1	70.0	76.4	66.9	66.1	70.0	76.4	66.9	66.1	70.0	76.4	66.9	66.1	70.0
1927	70.4	67.4	76.3	71.2	68.2	77.0	66.7	65.9	69.9	76.3	66.7	65.9	69.9	76.3	66.7	65.9	69.9	76.3	66.7	65.9	69.9	76.3	66.7	65.9	69.9
1928	70.2	67.2	76.2	71.0	68.0	76.9	66.5	65.7	69.8	76.2	66.5	65.7	69.8	76.2	66.5	65.7	69.8	76.2	66.5	65.7	69.8	76.2	66.5	65.7	69.8
1929	70.0	67.0	76.1	70.8	67.8	76.8	66.3	65.5	69.7	76.1	66.3	65.5	69.7	76.1	66.3	65.5	69.7	76.1	66.3	65.5	69.7	76.1	66.3	65.5	69.7
1930	69.8	66.8	76.0	70.6	67.6	76.7	66.1	65.3	69.6	76.0	66.1	65.3	69.6	76.0	66.1	65.3	69.6	76.0	66.1	65.3	69.6	76.0	66.1	65.3	69.6
1931	69.6	66.6	75.9	70.4	67.4	76.6	65.9	65.1	69.5	75.9	65.9	65.1	69.5	75.9	65.9	65.1	69.5	75.9	65.9	65.1	69.5	75.9	65.9	65.1	69.5
1932	69.4	66.4	75.8	70.2	67.2	76.5	65.7	64.9	69.4	75.8	65.7	64.9	69.4	75.8	65.7	64.9	69.4	75.8	65.7	64.9	69.4	75.8	65.7	64.9	69.4
1933	69.2	66.2	75.7	70.0	67.0	76.4	65.5	64.7	69.3	75.7	65.5	64.7	69.3	75.7	65.5	64.7	69.3	75.7	65.5	64.7	69.3	75.7	65.5	64.7	69.3
1934	69.0	66.0	75.6	69.8	66.8	76.3	65.3	64.5	69.2	75.6	65.3	64.5	69.2	75.6	65.3	64.5	69.2	75.6	65.3	64.5	69.2	75.6	65.3	64.5	69.2
1935	68.8	65.8	75.5	69.6	66.6	76.2	65.1	64.3	69.1	75.5	65.1	64.3	69.1	75.5	65.1	64.3	69.1	75.5	65.1	64.3	69.1	75.5	65.1	64.3	69.1
1936	68.6	65.6	75.4	69.4	66.4	76.1	64.9	64.1	69.0	75.4	64.9	64.1	69.0	75.4	64.9	64.1	69.0	75.4	64.9	64.1	69.0	75.4	64.9	64.1	69.0
1937	68.4	65.4	75.3	69.2	66.2	76.0	64.7	63.9	68.9	75.3	64.7	63.9	68.9	75.3	64.7	63.9	68.9	75.3	64.7	63.9	68.9	75.3	64.7	63.9	68.9
1938	68.2	65.2	75.2	69.0	66.0	75.9	64.5	63.7	68.8	75.2	64.5	63.7	68.8	75.2	64.5	63.7	68.8	75.2	64.5	63.7	68.8	75.2	64.5	63.7	68.8
1939	68.0	65.0	75.1	68.8	65.8	75.8	64.3	63.5	68.7	75.1	64.3	63.5	68.7	75.1	64.3	63.5	68.7	75.1	64.3	63.5	68.7	75.1	64.3	63.5	68.7
1940	67.8	64.8	75.0	68.6	65.6	75.7	64.1	63.3	68.6	75.0	64.1	63.3	68.6	75.0	64.1	63.3	68.6	75.0	64.1	63.3	68.6	75.0	64.1	63.3	68.6
1941	67.6	64.6	74.9	68.4	65.4	75.6	63.9	63.1	68.5	74.9	63.9	63.1	68.5	74.9	63.9	63.1	68.5	74.9	63.9	63.1	68.5	74.9	63.9	63.1	68.5
1942	67.4	64.4	74.8	68.2	65.2	75.5	63.7	62.9	68.4	74.8	63.7	62.9	68.4	74.8	63.7	62.9	68.4	74.8	63.7	62.9	68.4	74.8	63.7	62.9	68.4
1943	67.2	64.2	74.7	68.0	65.0	75.4	63.5	62.7	68.3	74.7															

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**No. 14. Resident Population, by Age and Sex: 1980 to 1997**

[In thousands, except as indicated. 1980 and 1990 data are enumerated population as of April 1; data for other years are estimates. Excludes Armed Forces overseas. For definition of median, see Guide to Tabular Presentation]

YEAR AND SEX	Total, all ages	Under 5 years	5-9 years	10-14 years	15-19 years	20-24 years	25-29 years	30-34 years	35-39 years	40-44 years	45-49 years	50-54 years	55-59 years	60-64 years	65+ years
<b>1980, total<sup>1</sup></b>	<b>226,546</b>	<b>18,348</b>	<b>16,700</b>	<b>18,242</b>	<b>21,168</b>	<b>21,319</b>	<b>19,521</b>	<b>17,561</b>	<b>13,965</b>	<b>11,669</b>	<b>11,230</b>	<b>11,710</b>	<b>11,615</b>	<b>10,088</b>	<b>15,511</b>
Male	110,053	8,362	8,539	9,316	10,755	10,663	9,705	8,677	6,862	5,708	5,388	5,621	5,482	4,670	6,711
Female	116,493	9,986	8,161	8,926	10,413	10,655	9,816	8,884	7,104	5,961	5,702	6,089	6,133	5,418	8,800
<b>1981, total</b>	<b>229,466</b>	<b>16,893</b>	<b>16,060</b>	<b>18,300</b>	<b>20,541</b>	<b>21,663</b>	<b>20,169</b>	<b>18,731</b>	<b>14,366</b>	<b>12,028</b>	<b>10,985</b>	<b>11,595</b>	<b>11,554</b>	<b>10,359</b>	<b>15,111</b>
Male	113,564	7,228	6,588	8,145	9,962	10,682	9,794	8,714	6,866	5,464	5,011	5,344	5,463	4,657	6,611
Female	115,902	9,665	9,472	10,155	10,579	10,981	10,375	10,017	7,500	6,564	5,974	6,251	6,091	5,761	8,500
<b>1982, total</b>	<b>231,064</b>	<b>17,228</b>	<b>15,968</b>	<b>17,145</b>	<b>19,962</b>	<b>21,182</b>	<b>20,141</b>	<b>19,067</b>	<b>16,117</b>	<b>13,150</b>	<b>11,201</b>	<b>11,414</b>	<b>11,463</b>	<b>10,557</b>	<b>16,111</b>
Male	114,792	7,547	6,838	8,381	9,981	10,632	9,741	8,677	6,862	5,708	5,388	5,621	5,482	4,670	6,711
Female	116,272	9,681	9,130	8,764	9,981	10,550	10,400	10,390	9,255	7,442	5,813	5,793	5,981	5,748	9,400
<b>1983, total</b>	<b>235,792</b>	<b>17,547</b>	<b>16,053</b>	<b>17,869</b>	<b>19,388</b>	<b>21,182</b>	<b>21,141</b>	<b>19,502</b>	<b>16,867</b>	<b>13,536</b>	<b>11,429</b>	<b>11,165</b>	<b>11,457</b>	<b>10,655</b>	<b>16,411</b>
Male	117,523	7,695	6,938	8,450	10,013	10,729	9,816	8,731	6,862	5,708	5,388	5,621	5,482	4,670	6,711
Female	118,269	9,852	9,115	9,419	9,375	10,453	11,325	10,771	10,005	7,828	6,081	5,544	5,975	5,985	9,700
<b>1984, total</b>	<b>237,924</b>	<b>17,842</b>	<b>16,665</b>	<b>17,027</b>	<b>18,727</b>	<b>21,263</b>	<b>21,671</b>	<b>20,625</b>	<b>17,604</b>	<b>14,087</b>	<b>11,606</b>	<b>10,854</b>	<b>11,229</b>	<b>10,906</b>	<b>16,111</b>
Male	119,138	7,963	7,098	8,474	9,813	10,744	9,893	8,731	6,862	5,708	5,388	5,621	5,482	4,670	6,711
Female	118,786	9,879	9,567	8,553	8,914	10,519	11,778	11,894	10,742	8,374	6,218	5,233	5,747	6,236	9,400
<b>1985, total</b>	<b>242,289</b>	<b>18,052</b>	<b>17,430</b>	<b>16,377</b>	<b>18,698</b>	<b>20,192</b>	<b>21,857</b>	<b>20,479</b>	<b>18,619</b>	<b>15,608</b>	<b>12,294</b>	<b>10,802</b>	<b>10,968</b>	<b>10,783</b>	<b>17,411</b>
Male	120,439	8,195	7,459	8,496	9,813	10,744	9,893	8,731	6,862	5,708	5,388	5,621	5,482	4,670	6,711
Female	121,850	9,857	9,971	7,881	8,885	9,448	11,964	11,748	11,756	9,900	6,886	5,181	5,486	6,113	10,700
<b>1986, total</b>	<b>245,819</b>	<b>18,508</b>	<b>17,917</b>	<b>16,797</b>	<b>18,133</b>	<b>19,258</b>	<b>21,560</b>	<b>21,676</b>	<b>19,455</b>	<b>16,960</b>	<b>13,421</b>	<b>11,212</b>	<b>10,534</b>	<b>10,707</b>	<b>17,111</b>
Male	122,711	8,741	8,005	8,324	9,177	9,747	10,706	10,865	9,836	6,741	5,494	5,494	5,009	4,947	7,111
Female	123,108	9,767	9,912	8,473	9,016	9,514	10,854	10,610	9,619	10,217	7,927	5,718	5,525	5,770	10,000
<b>1987, total</b>	<b>248,765</b>	<b>18,763</b>	<b>18,040</b>	<b>17,665</b>	<b>17,890</b>	<b>19,139</b>	<b>21,333</b>	<b>21,837</b>	<b>19,849</b>	<b>17,592</b>	<b>13,746</b>	<b>11,314</b>	<b>10,489</b>	<b>10,626</b>	<b>18,111</b>
Male	121,271	9,602	8,234	8,741	9,177	9,747	10,706	10,865	9,836	6,741	5,494	5,494	5,009	4,947	7,111
Female	127,494	9,161	9,806	8,924	8,713	9,392	10,627	10,972	10,014	10,851	7,252	5,820	5,479	5,679	10,999
<b>1988, total</b>	<b>252,124</b>	<b>19,187</b>	<b>18,198</b>	<b>17,653</b>	<b>17,732</b>	<b>19,177</b>	<b>20,715</b>	<b>22,152</b>	<b>20,524</b>	<b>18,761</b>	<b>14,101</b>	<b>11,651</b>	<b>10,424</b>	<b>10,582</b>	<b>18,111</b>
Male	125,002	9,489	8,285	8,668	8,717	9,085	10,152	11,237	10,092	8,806	5,362	4,209	4,487	4,440	6,411
Female	127,122	9,698	9,913	8,985	9,015	10,092	10,563	10,915	10,432	9,955	8,739	7,442	5,937	6,142	11,700
<b>1989, total</b>	<b>257,753</b>	<b>19,670</b>	<b>18,433</b>	<b>18,464</b>	<b>17,353</b>	<b>18,838</b>	<b>19,593</b>	<b>20,229</b>	<b>21,599</b>	<b>19,207</b>	<b>15,836</b>	<b>12,732</b>	<b>10,682</b>	<b>10,238</b>	<b>18,111</b>
Male	128,092	9,694	8,742	8,666	7,707	8,451	9,142	9,241	10,193	8,714	6,685	5,199	4,837	4,079	6,111
Female	129,661	9,976	9,691	9,800	9,646	10,387	10,451	11,088	11,406	10,493	9,122	7,533	5,845	6,159	12,000
<b>1990, total<sup>2</sup></b>	<b>265,179</b>	<b>19,324</b>	<b>19,425</b>	<b>18,949</b>	<b>18,644</b>	<b>17,562</b>	<b>18,993</b>	<b>21,388</b>	<b>22,550</b>	<b>20,809</b>	<b>18,438</b>	<b>13,931</b>	<b>11,362</b>	<b>9,997</b>	<b>18,111</b>
Male	131,748	9,801	9,757	9,527	9,827	9,470	10,340	10,340	11,266	10,596	9,074	7,383	5,646	4,745	8,111
Female	133,431	9,523	9,668	9,422	8,817	8,092	8,653	11,048	11,284	10,213	9,362	6,548	5,711	5,252	10,000
<b>1991, total</b>	<b>268,745</b>	<b>19,738</b>	<b>19,040</b>	<b>19,040</b>	<b>19,068</b>	<b>17,512</b>	<b>18,669</b>	<b>20,741</b>	<b>22,625</b>	<b>21,373</b>	<b>18,470</b>	<b>15,163</b>	<b>11,757</b>	<b>10,056</b>	<b>18,111</b>
Male	134,078	9,801	9,757	9,527	9,827	9,470	10,340	10,340	11,266	10,596	9,074	7,383	5,646	4,745	8,111
Female	134,667	9,937	9,283	9,513	9,241	8,142	8,329	10,401	11,359	10,777	9,396	7,780	6,111	5,311	10,000
<b>1992, total</b>	<b>271,245</b>	<b>19,738</b>	<b>19,040</b>	<b>19,040</b>	<b>19,068</b>	<b>17,512</b>	<b>18,669</b>	<b>20,741</b>	<b>22,625</b>	<b>21,373</b>	<b>18,470</b>	<b>15,163</b>	<b>11,757</b>	<b>10,056</b>	<b>18,111</b>
Male	134,078	9,801	9,757	9,527	9,827	9,470	10,340	10,340	11,266	10,596	9,074	7,383	5,646	4,745	8,111
Female	137,167	9,937	9,283	9,513	9,241	8,142	8,329	10,401	11,359	10,777	9,396	7,780	6,111	5,311	10,000
<b>1993, total</b>	<b>277,753</b>	<b>19,670</b>	<b>18,433</b>	<b>18,464</b>	<b>17,353</b>	<b>18,838</b>	<b>19,593</b>	<b>20,229</b>	<b>21,599</b>	<b>19,207</b>	<b>15,836</b>	<b>12,732</b>	<b>10,682</b>	<b>10,238</b>	<b>18,111</b>
Male	137,523	7,695	6,938	8,450	10,013	10,729	9,816	8,731	6,862	5,708	5,388	5,621	5,482	4,670	6,711
Female	140,230	11,975	11,495	10,014	7,340	8,109	10,081	11,506	14,737	13,128	10,128	7,111	6,193	5,568	11,400
<b>1994, total</b>	<b>280,192</b>	<b>19,694</b>	<b>18,742</b>	<b>18,566</b>	<b>17,707</b>	<b>18,451</b>	<b>19,142</b>	<b>22,141</b>	<b>21,973</b>	<b>19,714</b>	<b>16,685</b>	<b>13,199</b>	<b>10,837</b>	<b>10,079</b>	<b>18,111</b>
Male	140,138	8,451	7,707	8,566	7,707	8,451	9,142	9,241	10,193	8,714	6,685	5,199	4,837	4,079	6,111
Female	139,954	11,241	11,035	10,000	10,000	10,000	10,000	12,900	11,780	11,000	8,000	8,000	6,000	6,000	12,000
<b>1995, total</b>	<b>282,161</b>	<b>19,526</b>	<b>19,085</b>	<b>18,798</b>	<b>18,152</b>	<b>18,046</b>	<b>18,954</b>	<b>21,839</b>	<b>22,293</b>	<b>20,257</b>	<b>17,464</b>	<b>13,647</b>	<b>11,092</b>	<b>10,049</b>	<b>18,111</b>
Male	140,138	8,451	7,707	8,566	7,707	8,451	9,142	9,241	10,193	8,714	6,685	5,199	4,837	4,079	6,111
Female	142,023	11,075	11,378	10,232	10,445	9,595	9,812	12,646	12,100	11,543	8,749	8,448	6,255	5,970	12,000
<b>1996, total</b>	<b>285,179</b>	<b>19,324</b>	<b>19,425</b>	<b>18,949</b>	<b>18,644</b>	<b>17,562</b>	<b>18,993</b>	<b>21,388</b>	<b>22,550</b>	<b>20,809</b>	<b>18,438</b>	<b>13,931</b>	<b>11,362</b>	<b>9,997</b>	<b>18,111</b>
Male	141,748	9,801	9,757	9,527	9,827	9,470	10,340	10,340	11,266	10,596	9,074	7,383	5,646	4,745	8,111
Female	143,431	9,523	9,668	9,422	8,817	8,092	8,653	11,048	11,284	10,213	9,362	6,548	5,711	5,252	10,000
<b>1997, total</b>	<b>288,745</b>	<b>19,738</b>	<b>19,040</b>	<b>19,040</b>	<b>19,068</b>	<b>17,512</b>	<b>18,669</b>	<b>20,741</b>	<b>22,625</b>	<b>21,373</b>	<b>18,470</b>	<b>15,163</b>	<b>11,757</b>	<b>10,056</b>	<b>18,111</b>
Male	141,748	9,801	9,757	9,527	9,827	9,470	10,340	10,340	11,266	10,596	9,074	7,383	5,646	4,745	8,111
Female	147,000	9,937	9,283	9,513	9,241	8,142	8,329	10,401	11,359	10,777	9,396	7,780	6,111	5,311	10,000
<b>1998, total</b>	<b>291,245</b>	<b>19,738</b>	<b>19,040</b>	<b>19,040</b>	<b>19,068</b>	<b>17,512</b>	<b>18,669</b>	<b>20,741</b>	<b>22,625</b>	<b>21,373</b>	<b>18,470</b>	<b>15,163</b>	<b>11,757</b>	<b>10,056</b>	<b>18,111</b>
Male	141,748	9,801	9,757	9,527	9,827	9,470	10,340	10,340	11,266	10,596	9,074	7,383	5,646	4,745	8,111
Female	149,497	9,937	9,283	9,513	9,241	8,142	8,329	10,401	11,359	10,777					

**No. 14. Resident Population, by Age and Sex: 1980 to 1997**

[In thousands, except as indicated. 1980 and 1990 data are enumerated population as of April 1; data for other years are estimates. Excludes Armed Forces overseas. For definition of median, see Guide to Tabular Presentation.]

YEAR AND SEX	Total, all years	Under 5 years	5-9 years	10-14 years	15-19 years	20-24 years	25-29 years	30-34 years	35-39 years	40-44 years	45-49 years	50-54 years	55-59 years	60-64 years	65+ years
<b>1980, total<sup>1</sup></b>	<b>226,546</b>	<b>16,348</b>	<b>16,700</b>	<b>18,244</b>	<b>21,319</b>	<b>19,521</b>	<b>17,561</b>	<b>13,965</b>	<b>11,669</b>	<b>11,090</b>	<b>11,710</b>	<b>11,615</b>	<b>10,088</b>	<b>15,554</b>	
Male	110,053	8,362	8,539	9,316	10,755	10,663	9,705	8,677	6,862	5,708	5,388	5,621	4,470	6,711	
Female	116,493	7,986	8,161	8,928	10,564	10,655	8,816	8,884	7,104	5,961	6,089	6,133	5,418	8,843	
1981, total	229,466	16,853	16,060	18,300	20,541	21,663	20,169	18,731	14,366	12,028	10,965	11,595	11,554	10,359	15,611
1982, total	231,664	17,228	15,958	18,145	19,962	21,682	20,704	18,714	15,566	12,464	11,011	11,414	11,463	10,567	16,111
1983, total	233,792	17,547	16,053	17,863	19,388	21,632	20,141	19,067	16,117	13,150	11,201	11,155	11,457	10,855	16,411
1984, total	235,825	17,695	16,338	17,450	18,951	21,529	21,459	19,503	16,667	13,636	11,429	10,957	11,352	10,803	16,611
1985, total	237,924	17,842	16,665	17,027	18,727	21,265	21,671	20,025	17,604	14,368	11,606	10,854	11,229	10,906	16,811
1986, total	240,133	17,963	17,098	16,474	18,813	20,744	21,893	20,479	18,611	14,398	11,878	10,781	11,135	10,659	17,011
1987, total	242,289	18,052	17,430	16,377	18,698	20,192	21,857	20,984	18,619	15,608	12,294	10,802	10,968	10,783	17,411
1988, total	244,499	18,195	17,759	16,496	18,496	21,739	21,739	21,391	18,993	16,188	12,954	10,995	10,722	10,791	17,611
1989, total	246,619	18,333	17,977	16,797	18,133	19,258	21,560	21,676	19,455	16,960	13,421	11,212	10,534	10,707	17,811
<b>1990, total<sup>2</sup></b>	<b>248,765</b>	<b>18,763</b>	<b>18,040</b>	<b>17,065</b>	<b>19,139</b>	<b>19,139</b>	<b>21,333</b>	<b>21,837</b>	<b>19,849</b>	<b>17,592</b>	<b>13,746</b>	<b>11,314</b>	<b>10,489</b>	<b>10,626</b>	<b>18,011</b>
Male	121,271	9,602	9,234	8,741	9,177	9,393	10,706	10,865	9,836	8,679	6,741	5,494	5,009	4,947	7,011
Female	127,494	9,161	8,805	8,324	8,713	9,393	10,627	10,972	10,014	8,914	7,005	5,820	5,479	5,679	10,111
1991, total	252,124	19,187	18,198	17,653	17,232	19,177	20,715	22,152	20,524	18,761	14,101	11,651	10,424	10,582	18,211
1992, total	255,002	19,489	18,285	18,065	17,170	19,085	20,152	22,237	21,092	18,806	15,362	12,059	10,487	10,440	18,411
1993, total	257,753	19,670	18,433	18,464	17,353	18,838	19,593	22,229	21,599	19,207	15,936	12,732	10,682	10,238	18,611
1994, total	260,292	19,694	18,742	18,666	17,707	18,451	19,142	22,141	21,973	19,714	16,685	13,199	10,937	10,079	18,811
1995, total	262,761	19,526	19,083	18,798	18,152	18,046	18,954	21,839	22,293	20,257	17,464	13,647	11,092	10,049	18,711
1996, total	265,179	19,324	19,425	18,949	18,644	17,562	18,993	21,328	22,550	20,809	18,438	13,931	11,362	9,997	18,611
<b>1997, total<sup>3</sup></b>	<b>267,636</b>	<b>19,150</b>	<b>19,738</b>	<b>19,040</b>	<b>19,068</b>	<b>17,512</b>	<b>18,869</b>	<b>20,741</b>	<b>22,625</b>	<b>21,373</b>	<b>18,470</b>	<b>15,163</b>	<b>11,757</b>	<b>10,056</b>	<b>18,411</b>
Male	131,018	8,801	9,169	8,767	8,827	8,979	9,470	10,340	11,286	10,596	9,074	7,383	5,646	4,745	8,211
Female	136,618	9,349	9,569	9,273	9,241	8,532	9,399	10,401	11,338	10,777	9,396	7,780	6,111	5,311	10,211
<b>Percent:</b>															
1980 <sup>1</sup>	100.0	7.2	7.4	8.1	9.3	9.4	8.6	7.8	6.2	5.0	4.9	5.2	5.1	4.5	6.9
1990 <sup>2</sup>	100.0	7.5	7.3	6.9	7.2	7.7	8.6	8.8	8.0	7.5	6.2	5.5	4.5	4.2	7.3
1997	100.0	7.2	7.4	7.1	7.1	6.5	7.1	7.7	8.5	8.0	6.9	5.7	4.4	3.8	6.9
Male	100.0	7.5	7.7	7.4	7.5	6.9	7.2	7.9	8.3	8.1	6.9	5.6	4.3	3.6	6.9
Female	100.0	6.8	7.1	6.8	6.8	6.2	6.9	7.6	8.3	7.9	6.9	5.7	4.5	3.9	6.9

X Not applicable. <sup>1</sup>Total population count has been revised since the 1980 census publications. Numbers by age, race, Hispanic origin, and sex modified from the official 1990 census counts. See text, Section 1, for explanation. The April 1, 1990, census count (248,765,170) includes count resubmitted for adjustments for census coverage errors except for adjustments estimated for the 1995 Census test in Oakland, California, Patterson, New Jersey to a total of 55,297 persons.

Source: U.S. Bureau of the Census, *Current Population Reports*, P25-1095; and *Population Paper Listings* 91.

U.S. Census Bureau, the Official Statistics™ Statistical Abstract of the United States: 1998 Oct. 16, 1998

Figure 20. Fixplot for question 5



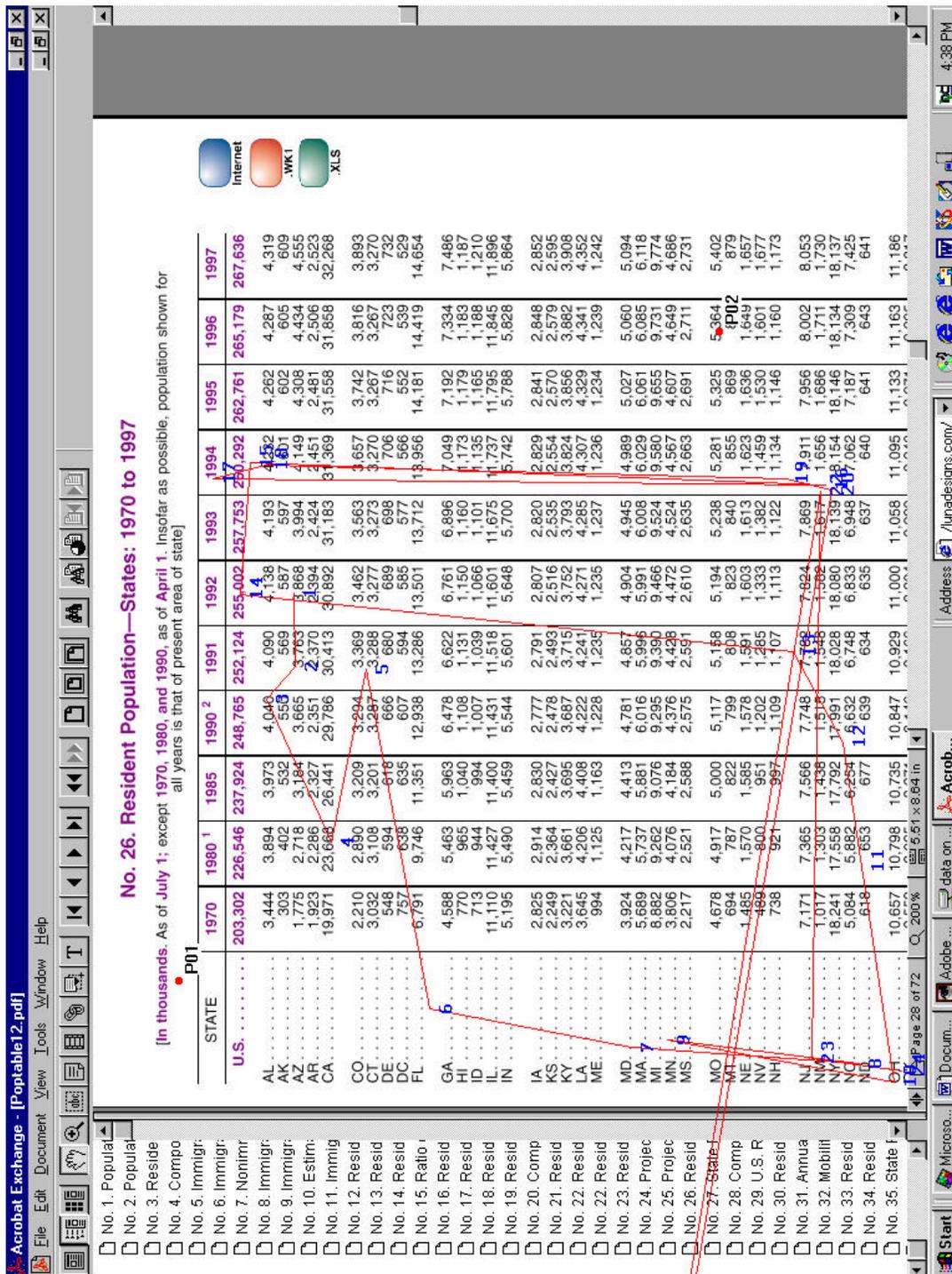


Figure 22. Fixplot for question 7

Acrobat Exchange - [Portable12.pdf]

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**No. 26. Resident Population—States: 1970 to 1997**  
 [in thousands. As of July 1; except 1970, 1980, and 1990, as of April 1. Insofar as possible, population shown for all years is that of present area of state]

STATE	1970	1980 <sup>1</sup>	1985	1990 <sup>2</sup>	1991	1992	1993	1994	1995	1996	1997
U.S. ....	203,302	216,546	237,924	248,765	252,124	255,002	257,753	260,292	262,761	265,179	267,636
AL .....	3,444	3,894	3,973	4,040	4,090	4,138	4,193	4,232	4,262	4,287	4,319
AK .....	303	402	532	550	569	587	597	601	602	605	609
AZ .....	1,775	2,116	3,184	3,863	3,763	3,868	3,994	4,149	4,308	4,434	4,555
AR .....	1,923	2,286	2,327	2,351	2,370	2,384	2,424	2,451	2,481	2,506	2,523
CA .....	19,971	23,666	26,441	29,786	30,413	30,892	31,183	31,369	31,556	31,743	32,268
CO .....	2,210	2,890	3,209	3,294	3,288	3,277	3,272	3,270	3,267	3,266	3,270
CT .....	3,032	3,108	3,201	3,287	3,288	3,277	3,272	3,270	3,267	3,266	3,270
DE .....	548	584	618	666	680	689	698	706	714	722	732
DC .....	757	789	835	897	894	895	895	895	895	895	895
FL .....	6,791	7,327	7,135	12,938	13,286	13,501	13,712	13,956	14,181	14,419	14,664
GA .....	4,588	5,383	5,983	6,478	6,622	6,761	6,896	7,049	7,192	7,334	7,486
HI .....	770	1,040	1,169	1,331	1,480	1,480	1,480	1,480	1,480	1,480	1,480
ID .....	1,713	944	984	1,007	1,069	1,066	1,101	1,135	1,165	1,198	1,210
IL .....	11,110	11,423	11,400	11,431	11,576	11,601	11,675	11,737	11,796	11,845	11,896
IN .....	5,195	4,990	5,459	5,544	5,601	5,648	5,700	5,742	5,788	5,839	5,864
IA .....	2,825	2,934	2,830	2,777	2,791	2,807	2,826	2,850	2,841	2,841	2,852
KS .....	2,249	2,377	2,377	2,493	2,516	2,516	2,516	2,516	2,516	2,516	2,516
KY .....	3,221	3,681	3,695	3,687	3,715	3,742	3,769	3,824	3,856	3,893	3,908
LA .....	3,645	4,006	4,408	4,622	4,241	4,271	4,285	4,307	4,330	4,351	4,352
ME .....	994	1,125	1,163	1,228	1,235	1,235	1,237	1,236	1,234	1,234	1,242
MD .....	3,924	4,238	4,413	4,761	4,657	4,604	4,645	4,689	4,727	4,760	4,794
MA .....	5,669	5,977	5,881	6,016	5,996	5,991	6,006	6,029	6,061	6,093	6,118
MI .....	8,882	9,262	9,076	9,295	9,390	9,466	9,524	9,580	9,655	9,731	9,774
MN .....	3,806	4,076	4,184	4,276	4,428	4,472	4,524	4,567	4,607	4,649	4,686
MS .....	2,217	2,521	2,588	2,575	2,591	2,610	2,635	2,663	2,691	2,713	2,731
MO .....	4,678	6,917	5,000	5,117	5,158	5,194	5,236	5,261	5,295	5,324	5,402
MT .....	694	787	822	799	808	803	840	855	869	879	879
NE .....	1,485	1,570	1,565	1,578	1,591	1,603	1,613	1,623	1,636	1,649	1,657
NV .....	489	806	921	1,202	1,285	1,333	1,392	1,459	1,530	1,601	1,677
NH .....	738	792	997	1,108	1,107	1,113	1,122	1,134	1,146	1,160	1,173
NJ .....	7,177	7,365	7,566	7,748	7,782	7,824	7,869	7,911	7,956	7,992	8,053
NM .....	1,017	1,303	1,438	1,515	1,548	1,582	1,617	1,656	1,686	1,711	1,730
NY .....	18,241	17,858	17,792	17,991	18,028	18,080	18,139	18,154	18,146	18,134	18,137
NC .....	5,087	5,882	6,254	6,632	6,748	6,833	6,948	7,062	7,187	7,309	7,425
ND .....	618	653	677	639	694	656	637	640	641	643	641
OH .....	10,657	10,795	10,735	10,847	10,929	11,000	11,058	11,095	11,133	11,163	11,186

Figure 23. Fixplot for question 8