LABORATORY 6 **Revised Version 03/11/04**

Measures of Attention and Processing Speed: Visual Scanning

Purpose

- to introduce the use of **reaction time** as a dependent variable in psychological research;
- to give you experience with **visual scanning** as a research tool;
- to give you practice using the **line of best fit** to measure psychological processes, in this case the speed of a mental process;
- to illustrate the notions of *parallel* and *serial* processing.

Introduction

We see the world by means of a continuous sequence of eye fixations and eye movements. During a single fixation, which typically lasts for 100 to 400 msec, we take in an enormous amount of information, then our eyes move to fixate on another location in the visual field and take in additional information, and so on in a constant flow of activity. Information from each fixation must be processed quickly so as to identify what objects and relations are present, and the processing must be completed before more information comes in from the next fixation. The time needed for such processing depends on both the amount of information to be processed and how rapidly each one of the objects contained in a fixation can be *scanned*. Although processing speed cannot be directly observed, it can be calculated from other measures that *are* directly observed. This lab will demonstrate the *method of additive factors* that cognitive psychologists use to measure the unobservable time needed for scanning.

The logic of the additive factors method uses three assumptions about measurement.

* **Measuring a single small unit can be accomplished by measuring a *large, known quantity* of small units then *dividing by the number of units*.** For example, to measure the thickness of a single sheet of paper with an ordinary ruler, measure the thickness of a stack of paper sheets, then divide by the number of sheets. If a ream of paper, which is 500 sheets, is 2 inches thick, then each sheet of paper is 2/500 or .004 (four thousandths) inches thick. [To measure something that is four thousandths of an inch thick with a ruler that has markings only to an accuracy of 1/16 of an inch (which is .0625 inches) or even 1/8 of an inch (which is .125 inches) seems like a remarkable accomplishment.].
* **The total time to complete a response is literally the sum of the times of separate processing steps.** Thus, if it takes 200 msec to complete visual decoding, 300 ms to complete scanning, and 500 ms to make a detectable response, the total time to respond is 200 + 300 + 500, or 1000 ms.
* **Some individual processing steps, such as pressing a response key, take the**

same amount of time regardless of the amount of information to be scanned. For example, if response execution takes 500 ms when scanning 1 item, it should only take 500 ms when scanning 4 items. The times for steps that stay the same can be treated as constants.

To illustrate the method used to calculate scanning time, suppose your task is to determine whether or not an "N" is among a set of 4 letters. A display of 4 letters is shown, you scan the set, find an "N" and press a key marked "Present" to end the trial. The time between the onset of the stimulus display and the completion of the key press is defined as your reaction time (RT) and is directly observable.

However, the observed RT is not simply a measure of how fast you scanned the 4 letters in the display. The observed RT includes the time needed to encode the display initially, defined as encoding time (ET), the time needed to scan the display, defined as scan time (ST), the time needed to make a decision, defined as decision time (DT), and the time needed to execute a movement, defined as motor time (MT). If encoding, scanning, deciding, and making a movement are assumed to be separate, independent steps in the total process, and if these steps are assumed to occur in sequence, then the observed RT can be expressed as the sum of the times for each of these steps, as shown in Equation 1:

$$RT_4 = ET_4 + ST_4 + DT_4 + MT_4 \qquad (1)$$

This equation states that the observed reaction time to find one letter among 4 alternatives (RT_4) is the sum of times to encode, to scan, to decide, and to make a movement when there are 4 alternatives (the subscript indicates that these times are for the case of 4 alternatives).

Now, suppose the task were changed slightly so that you had to find an "N" among a set of 16 letters, but in all other respects the task was set up in the same manner as the 4-letter task just described. In this case, you would scan a display of 16 letters until you found the "N", then you would press a response key marked "Yes". In this case the observed RT can likewise be calculated from the times for the steps of encoding, scanning, deciding and making a movement, as shown in Equation 2:

$$RT_{16} = ET_{16} + ST_{16} + DT_{16} + MT_{16} \qquad (2)$$

Common sense leads us to expect that finding an "N" among 16 letters should be harder than finding it among 4 letters, and we would expect RT_{16} to be greater than RT_4. But, in terms of our equations, where does the additional time come from? That is, which among the 4 separate steps takes more time, when the display contains 16 instead of 4 items?

Consider the encoding time. If “encoding time” refers to nothing more than the time to convert the visual display from visual energy to neural activation, then encoding time probably does not depend on display size. Hence, $ET_{16} = ET_4$.

Similarly, if movement time refers to just the time to initiate a movement, then movement time also should not depend on display size, and $MT_{16} = MT_4$.

Finally, if "decision time" refers to the time to decide what overt response to make, then decision time should not depend on display size either, and $DT_{16} = DT_4$.

According to this argument, the only step that takes more time between the task with a 4-item display and the task with a 16-item display is the "scanning time". There is more to scan with a display of 16 items rather than of 4 items, and, if scanning a single item takes a fixed amount of time, then more time will be needed to scan more items. In other words, if the reaction time for the 4 item display is subtracted from the reaction time for the 16 item display, the difference, $RT_{16} - RT_4$, is a direct function of the difference in time needed to scan 16 as compared to 4 items, that is, the difference $ST_{16} - ST_4$.

$$RT_{16} = ET_{16} + ST_{16} + DT_{16} + MT_{16} \qquad (2)$$
$$- \quad RT_4 = ET_4 + ST_4 + DT_4 + MT_4 \qquad (1)$$
$$\overline{\qquad\qquad\qquad\qquad\qquad\qquad}$$
$$RT_{16} - RT_4 = ST_{16} - ST_4 \qquad (3)$$

If we assume that the difference, $ST_{16} - ST_4$, is due simply to the time needed to scan the additional 12 items in the 16-item set than in the 4-item set, then this equation leads to a direct measure of the scanning rate:

$$RT_{16} - RT_4 = ST_{12} \qquad (4)$$

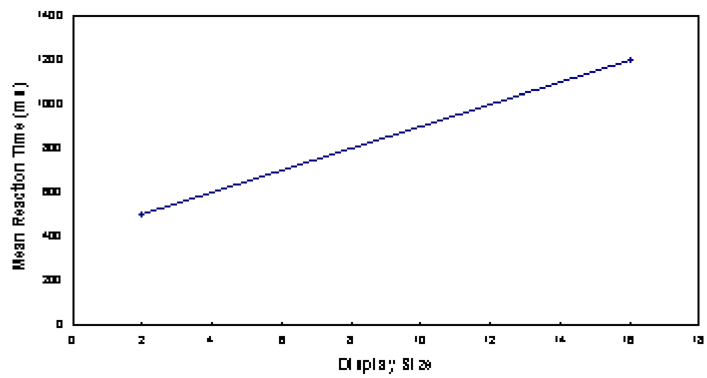
Furthermore, because we assume that it takes a fixed amount of time to scan each item, the time to scan 12 items equals the time to scan 1 item multiplied by 12. Conversely, the scanning time for one item, ST_1, is 1/12th of the scanning time for 12 items:

$$ST_1 = 1/12 * (RT_{16} - RT_4) \qquad (5)$$
$$= (RT_{16} - RT_4) / 12$$

This example shows how it is possible to obtain a measure of scanning time using two different display sizes. Suppose we use more display sizes, and include displays of 8 items, for instance, in addition to arrays of 4 and 16 items. Then, following the same argument described above for displays of 4 and 16 items, we could calculate an ST_8 from the RT_{16} and RT_8 and an ST_4 from the RT_8 and RT_4. Dividing the ST_8 by 8 or the ST_4 by 4 would yield other estimates of ST_1. With several different estimates, though, we need a way to choose a "best" estimate.

Using slope to measure processing speed

To illustrate how to get a best estimate of scanning time, I will use a pictorial representation of the data, plotting RT on the y-axis and the number of items in the display (or display size) on the x-axis. For this representation, the example described above yields 2 points, one representing RT_4 (for a display size of 4) and one representing RT_{16} (for a display size of 16).



The previous discussion reached the conclusion that RT_{16} is greater than RT_4 because of the additional scanning time needed in the case of RT_{16}. With a pictorial representation, this conclusion is equivalent to saying that the amount of increase on the y-axis, as display size goes up from 4 to 16 on the x-axis, is due to visual scanning time. In mathematics, any number that expresses a change on the y-axis relative to a change on the x-axis is a "slope". Thus, the measure of scanning time expressed in Equation 5 is related to the slope of the line that connects the data points for RT_{16} and RT_4 .

If more than 2 points are plotted (for example, if an RT_8 is also plotted), chances are good that the points will not all fall exactly on a single line. While it is possible to connect any *two* points with a straight line and find a slope for that line, different pairs of points would produce different lines, each with a different slope. What is needed is a way to draw a single line that takes into account all the points. Fortunately, finding a single line to represent multiple points is a familiar problem in statistics, where the accepted solution is to calculate a "line-of-best-fit" or "regression" line. Thus, if we find a line-of-best-fit, the slope of that line can be used to provide a measure of scanning time.

In this lab, you will measure your scanning rate under two sets of conditions. On trials in the Similar condition, the target letter will be visually similar to the non-target ("distractor") stimuli. On trials in the Dissimilar condition, the target letter will be visually different from the distractor stimuli. With these two conditions you can ask whether the scanning rate, and perhaps the nature of processing, depend on the stimuli as well as on your strategies.

Getting Started

This description of how to do the lab assumes that you are working on computers in the Psychology Lab, B-23 of Armitage Hall.

Turn on a computer, if it is not already on. (Be sure to check that it is not just in 'sleep' mode first). Click on "Start", select "Programs" from the menu that pops up, and click on "MS-DOS Prompt" from the list of programs. This will generate a window with a C:\WINDOWS> prompt displayed. Maximize the window, then type

m: and press "Enter".

At the M:> prompt, type

cd lab2004 and press "Enter",

then, at the M:\Lab2004> prompt, type

gwbasic vscan4u

and press "Enter". This should start the program on your machine.

The program begins with a request for a 3 digit random number; enter it. Next, the program requests that you enter the first 2 letters of your first name and the first 2 letters of your last name as a 4-letter sequence. The program will next ask you to indicate the number of the stimulus set; that you will get from the instructor.

The program will then ask you to indicate the keys to use for "yes, the target is present" and "no, the target is absent" responses. Your choice is either to use the "z" key for "Target Present (Positive)" responses and the "/" key for "Target Absent (Negative)" responses, or vice versa. If you want to respond with your left hand for "Target Present (Positive)" and your right hand for "Target Absent (Negative)", enter "z" in response the prompt. If you want to respond with your right hand for "Target Present (Positive)", enter "/" in response to the prompt. Think about which assignment seems more natural to you before making your choice and choose the more natural way of responding.

<u>Running the Activity</u>

The program presents instructions, gives you some practice trials, and generally provides guidance once it is started. If you make some awful mistake, just press the BREAK key. When you see OK on the screen, type RUN and press carriage return. That will restart the whole program.

At the end of the lab exercise, the program will store your data on the computer's hard disk and print a summary of your data on the computer monitor. The easiest way to get a copy of your data is to start a word-processing program, such as Word, WordPad or NotePad, and open the file with your data, then print it out. The file will be in the folder "Lab2004" on the M: drive, and it will have a name that begins "VS" followed by your 4-letter initials, with a "DAT" extension.

<u>Data Summary</u>.

The data summary is set up as follows:

SIMILAR SETS

2	0.866	0.135	0.774	10	1.033	0.120	0.893	11
4	0.863	0.038	0.866	10	... etc.			

down to
16 1.324 0.202 ...

These numbers are the data from the Similar condition. In each row, the first number (2, 4, etc.) is the display size. The next four numbers are, respectively, the mean RT, the standard deviation of the mean RT ( ), the median RT, and the number of correct responses (out of 12 total) for the Target Present or “YES” trials. The last four numbers are the mean, standard deviation of the mean, and median for RT's and the number of correct responses for Target Not Present or “NO” trials. That is, the columns have implicit headings as follows:

Display Size	Mean RT	SEM	Median RT	Nmbr Crrct	Mean RT	SEM	Median RT	Nmbr Crrct
2	0.866	0.135	0.774	10	1.033	0.120	0.893	11
4	0.863	0.038	0.866	10	... etc.			

Following these numbers come two rows as follows:

SLOPE: 0.031 PEARSON R: 0.911 STD Y: 0.177
SLOPE: 0.072 PEARSON R: 0.960 STD Y: 0.385

The first row gives you a summary for the YES trials. It shows the slope of the line of best fit for the median RT vs. display size function, the Pearson correlation coefficient for this line and the standard deviation of Y. The second row gives you the same information for the NO trials.

Following the slope information for Similar Sets, you have all of these kinds of information duplicated for the Dissimilar condition.

Data Analysis

The object of your data analysis is to determine how fast you can search your visual field, whether the speed depends on the type of materials, and whether you are doing a “parallel” search or a “serial” search.

Step 1. Transfer visual scanning data to spreadsheet

Enter the data for **mean** RTs in a spreadsheet. Use “2", “4", “8", and “16" as headings, and enter 4 rows of data, with the rows labeled Present (Sim), Absent (Sim), Present (Dis) and Absent (Dis).

Step 2. Plot the data with the Scatter Option

Use the **Scatter** option, with connecting lines, to create a chart that displays all 4 rows of data. Use the first row (with “2", “4", “8", “16") as data labels. (This means that you should select all 5 rows to make the chart).

Step 3.** Plot the data with the Lines Option (Optional)**

Create a second chart that displays all 4 rows of data, this time using the **Line** option, with connecting lines and symbols, and select the first row (the row of headings) to be the labels. How do the two charts differ? Why do they look different? Which one is the correct way to plot these data?

Step 4. Calculate the slope and intercepts for all the functions

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Calculate the slope and the intercept for **each row** of data, using the SLOPE and INTERCEPT functions in Excel. To get the slopes for each line, find four empty cells in the spreadsheet and type in

=slope(“range of y”, “range of x”),

in each cell, substituting the identification of the cells containing the *dependent variable* for “range of y” and identification of the cells containing the *independent variable* for “range of x”. Thus, your entry for Present (Similar) might look like:

=slope(b2:e2,b1:e1)

if you had put the display sizes in Row 1 and the data for Present (Similar) in Row 2.

To get the intercepts for each line, find another four empty cells and enter a similar set of commands, except for using “intercept” in place of “slope” as the name of the function.

Questions to Answer

1. The speed of processing is reflected in the slope of the search function, and the best estimate of processing speed is the **slope of the function for Target Absent**. Using this information, determine how fast you processed information in both the Dissimilar condition and in the Similar condition. In which condition did you process information faster?

2. The time needed to actually make the motor response is embedded in **the intercept of the search function**. Find the average of the intercepts for the two conditions

that involve Target Present and the average of the intercepts for the two conditions that involve Target Absent, then use this information to determine if the motor response time for making a response of ‘Yes’ (Target Present conditions) was the same as or different from the motor response time for making a response of ‘No’ (Target Absent conditions). If they are not the same, which condition was faster?

3. The analysis assumes that processing will generate straight line functions. Is this assumption supported by your data? Look at two things: the **squared** Pearson correlation coefficient (r^2), which is a measure of how well the data are fit by a straight line, and the graph. The closer the squared coefficient is to 1, the better the fit to a straight line. The graph will show a linear function or deviations from a linear function. If your data do not seem to fall on a straight line, how do they differ from what is expected? What kind of processing operations might have produced them?

4. Interpreting reaction time measures in terms of differences in processing time requires that the error rates for different conditions be eqivalent. Were your error rates roughly constant across the different conditions? If not, which conditions led to more errors? Does the pattern of errors suggest a speed-accuracy tradeoff?

5. Was your search in each condition more like a matter of ‘controlled’ processing or of ‘automatic’ processing? (* "Controlled" processing is indicated when scanning requires a slow, serial comparison of the target with each item in the visual field, whereas "automatic" processing is indicated when scanning involves a rapid, parallel-like comparison of the target with all objects in the field. The hallmarks of a slow, serial scan are that a) scanning rates are relatively high and b) the slope for negatives is about 2 times the slope for positives. The hallmarks of a fast, parallel scan are that a) scanning rates are relatively low and b) the slopes for negatives and positives are close in magnitude).

Lab Report

Your report of this lab will consist of:

1) a title page; and
2) a results section which includes the graph from Step 2 of the Data Analysis (the graph using the *Scatter* option), with the graph properly drawn and labeled, and your answers to the 5 *Questions to Answer*.
3) a copy of your spreadsheet (from Step 1 of the Data Analysis section.

In your report, be sure to explain the reasoning behind your conclusions.