Determining Rate of Change and Predicting Performance Levels in Aphasia Therapy

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In aphasia, studies that have attempted to predict optimum duration of treatment, attainment of ultimate goals, and define the natural evolution of the disorder, have generated a far greater number of questions than answers. For example: Can the treatment data which we have been encouraged to collect be used to estimate the rate of change in a patient's performance on specific treatment tasks? Is the performance increase for communication tasks linear or curvilinear? How effective are different intervention strategies for individual aphasic patients? What levels of performance can an individual expect to achieve in treatment? Given a specific rate of change, how long must treatment continue to reach a set criterion?

All of these questions relate to predicting the future performance of aphasic people and are of paramount concern to the clinical aphasiologist, the patient, family members, and other medical and rehabilitation professionals. Unfortunately, aphasiologists have focused little research attention on these issues (LaPointe, 1980). In the past, the approach to prediction has been to classify patients according to prognostic variables and behavioral profiles. These two systems, although clinically practical, tend to be vague, because of their descriptive nature. More specific numerical data have been reported recently by those who have analyzed progress by multiple regression (Porch, Collins, Wertz, Friden; 1980). Unfortunately, the statistical procedures may be somewhat limited in clinical practicality since some clinicians may not have access to the necessary computer equipment.

LaPointe (1980) illustrated the concept of reacquisition rate, and established that understanding trends or celeration rates, and applying methods for estimating trend must precede analyzing, evaluating and predicting the potential effects of treatment. Clinical aphasiologists have been collecting treatment data but have not yet reported trend estimations, perhaps because we have been unaware of clinically practical tools for measuring it.

In searching the literature, we noticed that other behavioral disciplines, such as education and experimental psychology, have used a quick procedure to estimate trend and predict performance. Intrigued by their results, we applied the technique to some aphasia data, and proceeded to develop some formulae and a trigonometric table for evaluating data and predicting the potential effect of treatment when rate of change remains constant.

We propose these methods today, not as a clinically proven means to predict, but as a potential foundation on which to build, as all of us develop the procedures which will enable us to answer the projective questions asked by aphasiologists and their clientele. The methods may appear complicated at first, but we hope that we can whet your appetite to learn them and put them to the clinical test by showing their potential usefulness.

THE QUARTER INTERSECT METHOD FOR ESTIMATING TREND

The quarter intersect, or split middle technique for estimating trend or progress is a four step procedure which does not necessarily require computers or statistical programs and, once learned, can be done in less than two minutes. Incidently, when we correlated the results of the quarter intersect method, which we shall explain in a minute, with the traditionally derived least squares estimations of trend, we found a high and comforting correlation.

To demonstrate the procedure, let's view some data which shows a hypothetical patient's progress on a naming task. Figure 1 illustrates data points which represent a hypothetical aphasic patient's scores as measured for 14 consecutive sessions.

Step One. The first step of the quarter intersect procedure is to divide the data in half using a vertical line, as we have illustrated by the dotted line in Figure 2. One way quickly to locate the vertical midline is to consult Table 1. Since there are 14 data points, first find 14 in column 1, which is labeled "Quantity of Data Points." Next find the corresponding number in column 2, labeled "midline," which in this case in the number 7.5. As you can see on the graph, the vertical line drawn to intersect 7.5 on the X or horizontal axis, divides the data in half. We find it useful to label the left half L and the right half R for reference purposes.

Table 1. Locating critical points on the graph.

1 Quantity of Points	2 Midline	3 Median X-value(L)	4 Median X-value(R)	5 Median Y-Count	6 Trend-Line Division
6	3.5	2	5	2	3
7	4	2	6	2	3-4
8	4.5	2.5	6.5	2-3	4
9	5	2.5	7.5	2-3	4-5
10	5.5	3	8	3	5
11	6	3	9	3	5-6
12	6.5	3.5	9.5	3-4	6
13	7	3.5	10.5	3-4	6-7
14	7.5	4	11	4	7
15	8	4	12	4	7-8
16	8.5	4.5	12.5	4-5	8
17	9	4.5	13.5	4-5	8-9
18	9.5	5	14	5	9

Step Two. For each half, find the median X-value; that is, find the mid-data point along the horizontal axis for the first half, L and then for the second half, R. To do this, you may consult Table 1. Find 14 in

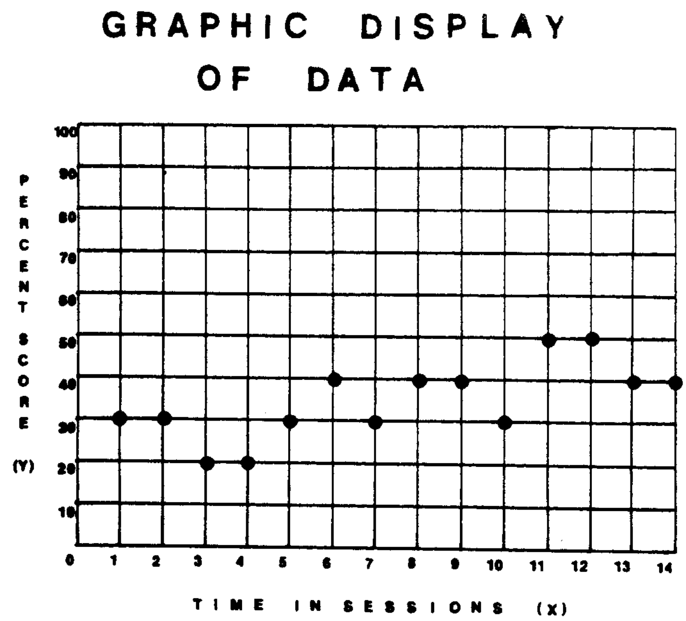

Figure 1. Scores of hypothetical patient.

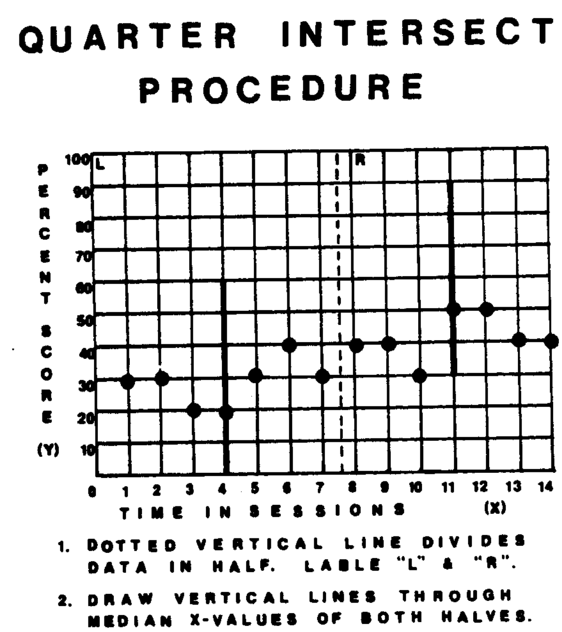

Figure 2. Dividing the scores.

column 1. Follow across to column 3 to find the value for L, which is 4, and then look at column 4 to find the value for R, which is 11. On Figure 2, a solid, vertical, line depicts the median X-value location for each half.

Now the number of data points has been divided into 4 equal parts or quarters.

Step Three. The next step is illustrated in Figure 3. To accomplish this step, first consult Table 1. Again, find 14 in column 1 because of the 14 data points. Next locate the corresponding number in column 5, which is labeled "Median Y-Count." The number is 4. You may have asked: "What is a median Y-count?" If all the scores in each half were arranged in either ascending or descending order, and then counted, the median Y-count corresponds to the middle point of each half. In this case, the median Y-count is 4. Therefore, beginning at the top or bottom of L, count each data point, being careful to include equivalent or tied scores. Stop counting at the median Y-count value, 4. Draw a horizontal line through it and repeat the procedure for the second half of the data. The two horizontal lines on Figure 3 are the result.

As we show on Figure 3, each vertical median line which we drew in step 2 intersects with the corresponding horizontal median line of step 3 for each half of the data.

Step Four. Now we are ready to discover the celeration rate or trend of this patient's progress. We use a ruler to connect the two points of intersection and to extend that line through all data points. In this case, that includes session 1 through 14. Sometimes, as in cases where a large number of ties or equivalent scores occur in determining the median Y-count, the line which we draw in this step does not result in an equal distribution of scores above and below the intersecting line. If this occurs, a slight line adjustment is necessary. Here is how to adjust the line: Consult Table 1, column 6, labeled "Trend-Line Division." We have calculated the number of data points which should appear above and below the completed trend line. For 14 data points, 7 points should be above the trend line and 7 should be below it. Now, back to the data display, we can verify the location of the line we drew by counting the number of points above the line. There are 7, as Table 1 suggests there should be.

Therefore, the diagonal line on Figure 4 represents the quarter intersect's estimation of the trend of the patient's progress on his naming task. Had the number of points above the line not agreed with the trend line division number and needed slight adjustment, we would have used a ruler to draw a line parallel to the trend line, but one which did bisect the data, and that would be the estimated trend or slope of progress.

Now that we have a visual representation of the progress being made, we can quantify it in terms of rate or speed of change. This can be done by figuring out the slope of the line and the degree of celeration.

In Figure 5, we illustrate that for each unit of progress in his score, or for each 10% gain, this aphasic man took 7 units of time, or 7 sessions. The slope of the line is therefore 1/7, or .14.

To convert this to degree of slope, look at Table 2. Under column 2, "slope," we find the value which most nearly approximates the slope of the line, .14. If we look at the column to the left of that value we find that a slope of .14 is equal to an 8° celeration rate. The same value, 8°, would result had we used a protractor to measure the acute angle between the slope line and any horizontal line intersected by it.

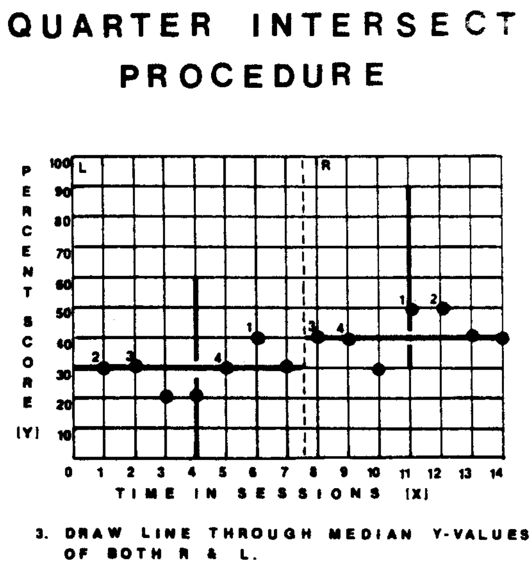

Figure 3. Determining median Y values.

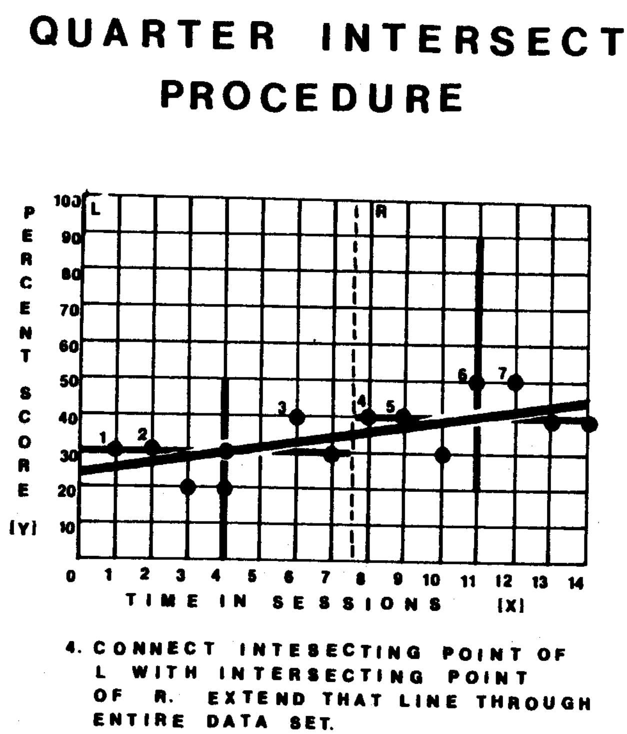

Figure 4. Estimating trend.

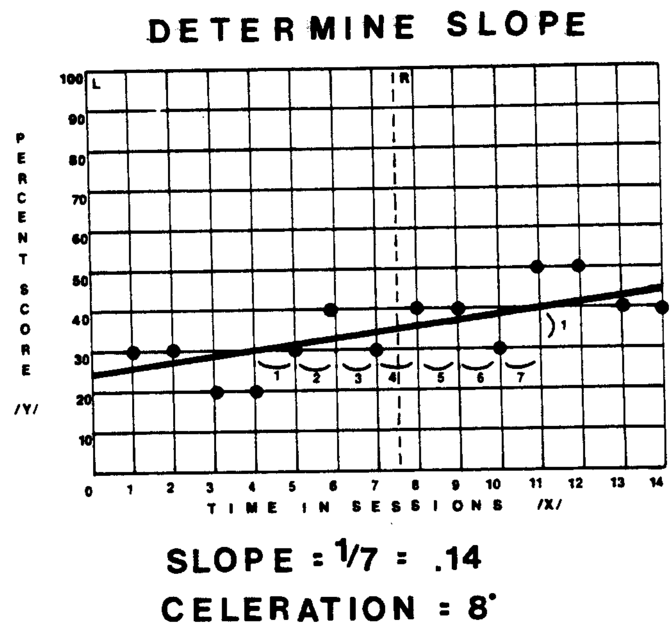

Figure 5. Quantification of celeration rate.

Table 2. Estimating number of sessions per X% change.

1 Degree	2 Slope	3 10%	4 20%	5 30%	6 40%	7 50%	8 60%	9 70%	10 80%	11 90%	12 100%
5	.09	11	23	34	46	57	69	80	91	103	114
6	.11	10	19	29	38	46	57	67	76	86	95
7	.12	8	16	24	32	41	49	57	65	73	81
8	.14	7	14	21	28	36	43	50	57	64	71
9	.16	6	13	19	25	32	38	44	51	57	63
10	.18	6	11	17	23	28	34	40	45	51	57
11	.19	5	10	15	21	26	31	36	41	46	51
12	.21	5	9	14	19	24	28	33	38	42	47
13	.23	4	9	13	17	22	26	30	35	39	43
14	.25	4	8	12	16	20	24	28	32	36	40
15	.27	4	7	11	15	19	22	26	30	34	37

Now we can see that the data collected progresses at a rate of 8°, and that the person has been gaining about 10 percentage points for every 7 treatment sessions. We can combine that information with the peaks and valleys of the data configuration to determine the patient's range in performance, as is illustrated by the trend envelope of Figure 6.

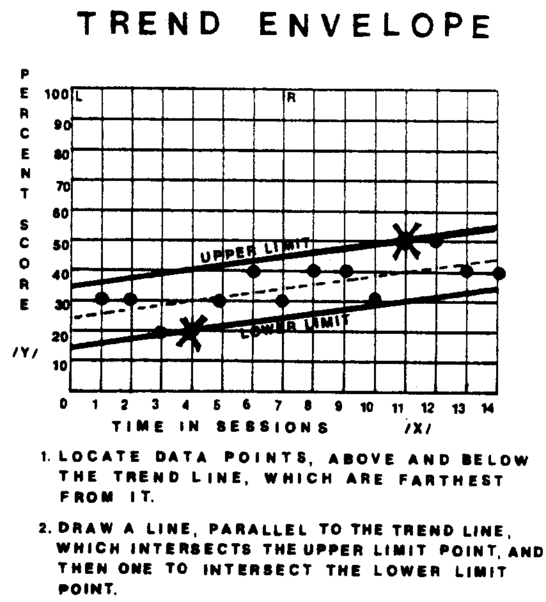

Figure 6. Determining range of performance.

The trend envelope defines the upper and lower limits of the patient's performance and it celerates at the same rate as the trend line. In order to construct a trend envelope, first locate the data point above the trend line which is farthest from it, and then draw a line which intersects that point and is parallel to the trend line. That line is the upper limit of the trend envelope. Now locate the point which is farthest below the trend lind. The lower limit of the trend envelope intersects that point and is also parallel to the trend line. Draw it to complete the trend envelope, as we show by the parallel lines on Figure 6.

Now we have defined the range of the scores or data points, within an envelope whose celeration rate corresponds to the estimated trend of 8°. Can we use the information to predict the patient's future performance on the task? If we continue to treat him and collect data on his progress, can we know if he is continuing at the same rate of progress, or if he is gaining or losing momentum with exposure to the task? We can, if we use the trend envelope displayed on Figure 6 to construct a prediction envelope as we show in Figure 7.

We have extended the upper and lower limits of the trend envelope for equal distances. The resulting envelope predicts the probable range of performance if progress were to continue at the measured rate of 8°. New data can be visually compared to the prediction envelope and evaluated relative to the early trend or progress rate.

Figure 8 shows one possibility for a data configuration if measurement were to be continued for 14 more treatment sessions. How many data points in the second half actually fell within our predicted range? Ten out of 14,

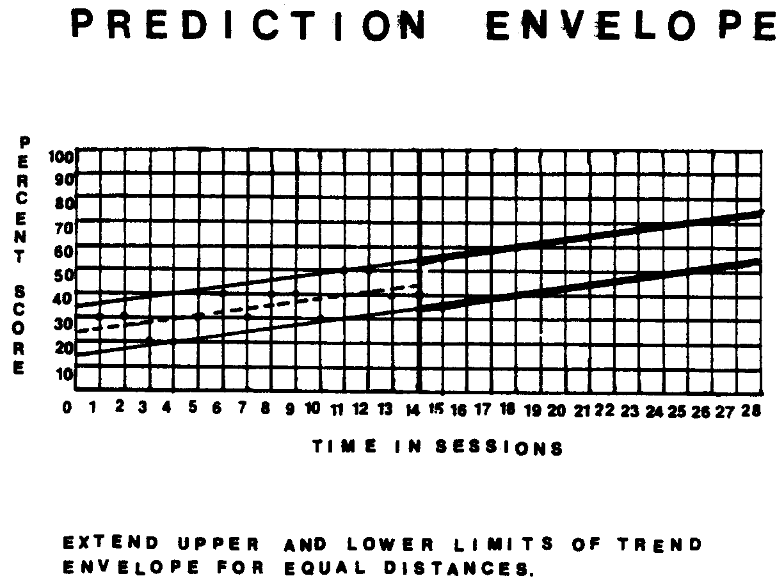

Figure 7. Constructing a prediction envelope.

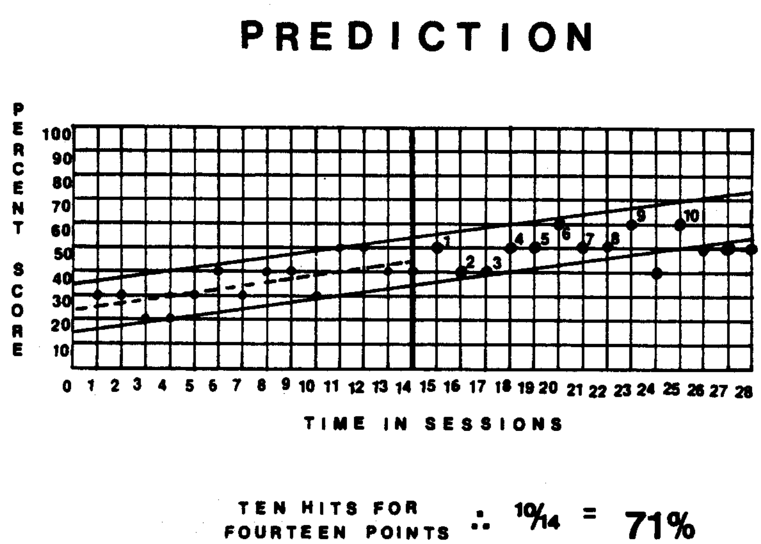

Figure 8. Plotting performance against prediction.

or 71% of the scores collected were accurately predicted by the envelope in this case.

We have devised some methods for evaluating the data further. Several questions concerning progress and prediction can be answered by these methods. For example: How many sessions will it take to achieve a gain of 10%...of 20%...or, of 100%? How long will it take to reach a preselected criterion? At what level will the patient perform after a predetermined duration of treatment?

CONCLUSION

Time limitations do not allow a detailed explanation of the formulae and trigonometric table which we have adopted; but we are looking forward to discussing them in future work.

Predictive validity of the tables, formulae, and constructions depend on one condition; that progress continue at the measured rate. Although several have reported that recovery patterns for aphasic individuals seem to be lawful (Sidman et al., 1971; Ulatowska and Richardson, 1974) the nature of the patterns has not yet been determined and we do not know if trend continues at a constant rate or if it changes as treatment ensues. The methods described in this paper may provide an easily constructed standard by which to examine patterns of recovery and to determine the conditions which surround various patterns. By applying these methods to real data, we will find if they are valid predictive tools. We may also discover how recovery patterns vary according to such factors as aphasia type, treatment approach, task type, early data configuration, or early performance level. We may determine conditions that surround various patterns of change, or find the proportion of points which can be predicted beyond data already in hand.

We would be delighted if the suggestions presented in this paper served as a catalyst to further clinical exploration that would shed some light on the vital questions surrounding progress, prediction, and recovery in aphasia.

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