Title
The Effect of Instructions on Visual and Task Performance

Permalink
https://escholarship.org/uc/item/1hj0d8r5

Authors
Clear, R.
Berman, S.

Publication Date
1990-02-01

LBL-28548
Preprint

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

APPLIED SCIENCE DIVISION

Submitted to The Journal of the Illuminating Engineering Society

The Effect of Instructions on Visual and Task Performance

R. Clear and S. Berman

February 1990

APPLIED SCIENCE DIVISION

Prepared for the U.S. Department of Energy under Contract Number DE-AC03-76SF00098

DISCLAIMER

Published in the Journal of the Illuminating Engineering Society, Winter 1991.

LBL-28548
L-145

THE EFFECT OF INSTRUCTIONS ON VISUAL AND TASK PERFORMANCE

Robert Clear and Sam Berman

Lighting Systems Research Group
Applied Science Division
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

February 1990

This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Buildings and Community Systems, Building Equipment Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

The Effect of Instructions on Visual and Task Performance

Robert Clear and Sam Berman

Introduction

In a previous paper we analyzed Rea's data from a numerical verification (NV) experiment. We used a model based on discrete eye fixations, with fixation duration, composed of visual and nonvisual components.[1,2] The present paper investigates one of the implications of this model, which involved an experiment on the effect of instructions on performance on the NV task. On any task requiring discrete eye fixations, the number of fixations needed for the task and the minimum time required per fixation puts a lower bound on the time to complete the task. The minimum time per fixation has been reported to be on the order of 200–300 ms for simple tasks.[3] The two columns of numbers in the NV task are separated by about 7 degrees, which makes it difficult to clearly see them both in one fixation.[4] On the other hand, a single five-digit number is only about 1.4 degrees across, so it should be visible in one fixation. This leads to an estimate of a minimum of 40 fixations to complete the task, and thus an estimate of 8–12 s as a minimum time per chart.

The average time for Rea's subjects at high visibilities was over twice our calculated minimum, even after correcting for action times. The estimated visual component of task time in our model is only about 10 ms per number at the high visibilities. We estimated the nonvisual component of task time for Rea's subjects to be about 650 ms per number by assuming subjects viewed each number only once unless there was a mismatch. This value is much higher than our minimum estimate. Therefore we wondered if the task could be done more quickly.

The procedures used in these NV experiments are described in two papers by Rea. Subjects were told to quickly and accurately compare the reference and test numbers. Of particular interest to us was Rea's comment that one subject's results were dropped because of a shift in response strategy during the second experiment.[2] We had previously suggested that the nonvisual component time was cognitive.[1]

Rea's comment on response strategy made us suspect that the speed at which the subjects performed the NV task could be manipulated by changing the instructions. We therefore tested subjects with two sets of instructions: one emphasizing speed, and the other emphasizing accuracy. Response times under the accuracy instruction were similar to those measured by Rea, while times under the speed instruction were significantly shorter.

Methods and procedures

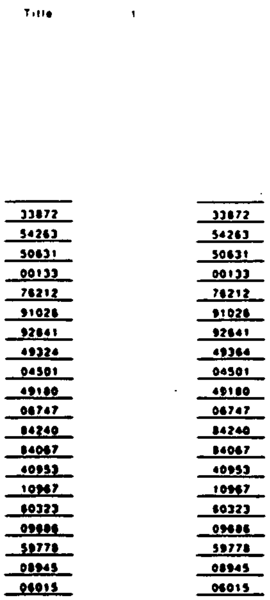
The NV task requires the subject to compare two columns of numbers and to mark any pair that is not identical. Our experimental design covered only a few visibility conditions; otherwise, it is similar to that of previous experimenters.[2,3,5,6,7]

Test sheets—The experiment used a set of 80 test sheets, each with two columns of 20 five-digit numbers. A spreadsheet program (Macintosh EXCEL) was used to generate the numbers and to accumulate information about the test sheets. The numbers in the first column were generated using the spreadsheet's pseudorandom number generator. The first column was duplicated in the second column. Then the random number generator was called again for each number to decide whether a number should be changed, and if so, to decide which digit should be changed and to what.

The number of unmatched pairs per test sheet averaged 3.05 with a range of zero to six for the set. Test sheets were grouped in blocks of five and reordered so that each test condition had approximately the same number of mismatches. There were no statistically significant trends for location or type of mismatch.

The test stimulus was designed to be similar to those in the Rea experiments.[2,5] The numbers were printed in 10-point Helvetica at 300 dots per inch on a LaserWriter Plus. Digits are approximately 2.8 mm high by 1.9 mm wide. A five-digit number is about 1.2 cm wide. The number field covers an area 11.8 cm high by 7.4 cm wide, with about 6.2 cm between the centers of the two number columns. Lines above and below the numbers were created by printing the top and bottom borders of the 15.7-by-17-point (row-column) Excel grid cells. The top of the test sheet contains the series name, the test sheet number, and a 15-mm calibration dot. **Figure 1** shows a sample test sheet. Test sheets were reproduced on regular 20-pound office copy paper. High-contrast sheets were reproduced directly on an office copier. Low-contrast sheets were printed with a standard Pantone cool-gray 2U color density ink by the lab print shop.

Authors' affiliation: Lawrence Berkeley Laboratory, Berkeley, CA



Title 1

33872	33872
54263	54263
50831	50631
00133	00133
78212	78212
91028	91028
92841	92641
49324	49364
04501	04501
49180	49180
08747	06747
84240	84240
84067	84067
40953	40953
10967	10967
60323	60323
09886	09686
59778	59778
08945	08945
06015	06015

Figure 1—Format of test sheet used in experiment

Test room and setup—The experiment was set up in a small meeting room with its single window blocked off. The subjects sat at a large dark orange table facing a black drape on the far wall. Subjects used a chin rest to maintain approximately 50 cm in distance, and 42 degrees above straight down in viewing angle, from the center of the target.

Lighting and photometry—Luminances and contrasts were measured with a Tektronix J6523-2 1-degree luminance probe mounted on a J16 digital photometer. Overhead warm-white fluorescent lights were used for the high luminance condition, while indirect light from a portable warm-white fluorescent desk lamp aimed at the ceiling was used for the low luminance condition. The lights were not voltage regulated, and the luminance standard deviation was about ±2.5 percent. Because the ink mixture was less than perfectly homogenious, there was about a ±5 percent standard deviation in contrast among sheets with the gray ink. Table 1 presents the luminances, contrasts, and VLs calculated from both Blackwell's and Rea's threshold contrast formulas for the four test conditions.[2,8] The Blackwell VL values are 2.5 times larger than values calculated from the CIE 19/2 reference because we have not corrected the detection thresholds from Blackwell's forced choice method to the CIE method of adjustments.[1,8] The background luminances of the gray ink test sheets are slightly higher than those of the black ink test sheets because the 20 lb bond test sheets were slightly translucent. The print from the test sheets below the viewed sheet slightly darkens the area in the immediate vicinity of the test numbers. Note that the contrast for the low-luminance, high-contrast condition was estimated by scaling the luminance of the black test dot at high luminances by the ratio of the luminances of the gray dots in the low and high luminance test conditions. Our luminance probe could not read low enough to make the measurement directly with any precision.

Test Conditions				VL Threshold contrast formula	
Luminance	Contrast	Luminance(cd/m^2)	Contrast	Blackwell	Rea
High	High	264	0.905	28.0	18.4
High	Low	273	0.260	8.1	5.3
Low	High	4.40	[0.909]	10.6	10.4
Low	Low	4.56	0.285	3.4	3.3

Notes: [...] indicates an estimate (see text)
VL = Contrast(physical) / Contrast(at threshold)

Table 1—Test visibility conditions

Protocol—The subjects first read a general instruction sheet explaining the purpose of the experiment, and then did a minimum of four practice runs, one at each contrast and instruction condition. Questions about the experiment were answered at this time. Questions were discouraged during the actual testing. The eight test conditions were presented in blocks of ten runs each, with an extra practice run at the beginning of each block. Conditions were nested: luminance changed once, contrast three times, and instructions five times. There were no changes in instruction for two of the contrast changes. The tests generally took an hour and more, with a break midway to adapt to change in luminance condition. The luminance and instruction blocks were presented in an order counterbalanced among the four test subjects. The subjects were volunteers, and were not paid. The instruction emphasizing accuracy was, "You can imagine that you are being paid by the number of test charts you read per hour, but that there is a penalty for making mistakes. Your (imaginary) pay rate is 40 cents per chart, and the penalty rate is $1 per error. Both speed and accuracy are important, but with this condition you should make ***accuracy*** the more important of the two. Try to make sure that you are certain of the number in the left column before shifting your gaze to the right column, so that you do not have to go back and forth. Try to make sure that you read each digit so that you do not miss the center digits. Try to do the task accurately and quickly."

The instruction emphasizing speed was, "You can imagine that you are being paid by the number of test charts you read per hour, but that there is a penalty for making mistakes. Your (imaginary) pay rate is 25 cents per chart, and the penalty rate is 15 cents per error. Both speed and accuracy are important, but with this condition you should make ***speed*** the more important of the two. To increase your speed, try to get a good look at the number without actually reading it, so that instead of comparing two numbers you are comparing two visual images. If this is not possible for you, at least try to read the number as a whole instead of reading the digits one by one."

The experiment began when subjects indicated that they understood the instructions and were ready. Subjects were not given feedback on their performance during the experiment.

Observers—The subjects were a sample of lab employees. The subjects were not involved in vision research, and one subject rarely does numerical tasks. Subjects were 22–38 yrs old. Three were male. All subjects reported normal vision, but no confirming checks were made.

Data collection and analysis—A stopwatch measured the time between the experimenter's start of the experiment and the subject's stop of the experiment. The accuracy of this procedure was tested by having a subject with a second stopwatch time himself from a countdown to a stop chosen by the subject. The experimenter timed the same event from the auditory cues alone. The two times matched to within 0.2 s and showed no significant bias. A colleague who has timed swim meets noted that this was the maximum difference he had seen between electronic and manual timing of swimmers. He also noted that the error is not affected by the duration of the event.

Subjects marked mismatches by checking them or ruling them out. The location of the marks was recorded with the aid of a transparent overlay after the experiment. A spreadsheet macro program then determined whether the recorded value was a hit or false-positive and tabulated the number of missed mismatches and total marks.

Accuracy was calculated in our analysis as the number of correct identifications of mismatches (hits) divided by the sum of the number of rows marked (which includes false positives) and the number of true mismatches missed. No subject had more than two false positives in an entire run. Like other researchers, we have assumed that the extra time needed to make marks is not primarily visual, and we therefore corrected our raw times by an amount proportional to the number of marks on a given sheet. The correction time was determined separately for each subject from a fit to the times that included the number of marks. Corrections ranged from 0.5 to 1.8 s per mark. The times are comparable to the 0.8 s per mark used by Rea.[2]

Results

The average accuracies and times, and their standard errors, for each of the four subjects as a function of the conditions are given in **Table 2. Figures 2a** and **2b** plot the times and accuracies respectively, as averaged over subjects. **Figures 3a** and **3b** plot the differences in performance between speed and accuracy instruction conditions. The plots should make these differences clearer. The data in **Figures 3a** and **3b** are not averaged over subjects. In all four figures we used VLs calculated with Rea's thresholds instead of the CIE reference values because the Rea values were measured specifically with this type of task. As **Table 1** shows, the two methods give similar values so the results are not critically dependent upon this choice. The times reported in **Figures 2a** and **3a** have been reduced by the time correction for marks mentioned in the data analysis section. The predicted times in **Figure 2a** are based on a fit to the data from Rea's experiment. The fit is a simplified version of the fit described by Clear and Berman.[1] It is described below for the reader's reference:

$$T = T_{nonvisual} + T_{visual} \sim N[T_o + (aV)/(B \cdot VL - V)] \qquad (1)$$

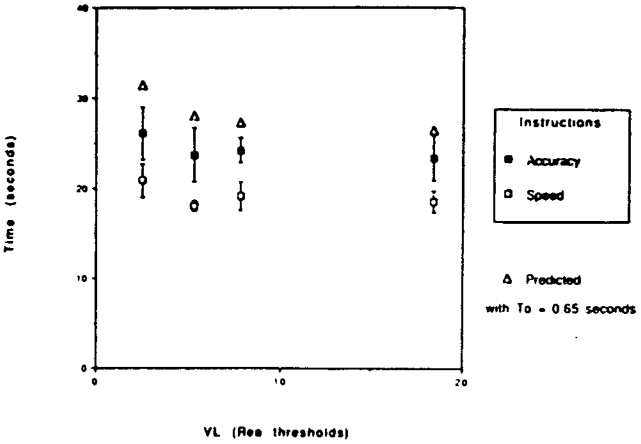


Figure 2a—Time to complete chart (averaged) vs visibility and instructions.

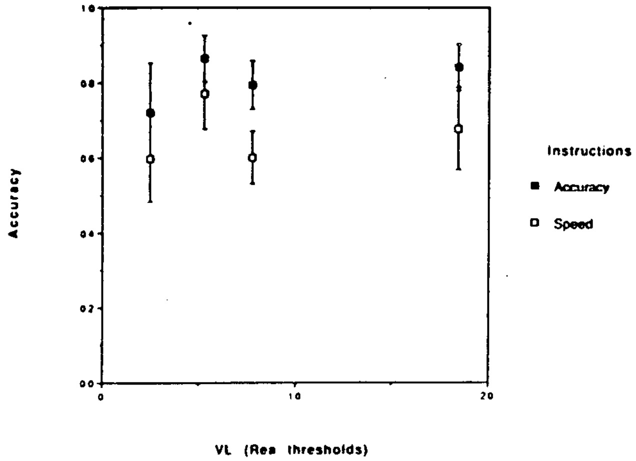


Figure 2b—Accuracy (averaged) vs visibility and instructions

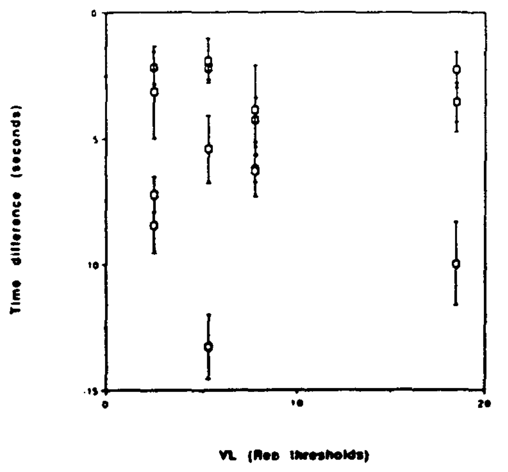


Figure 3a—Time to complete chart with speed instruction minus time with accuracy instructions

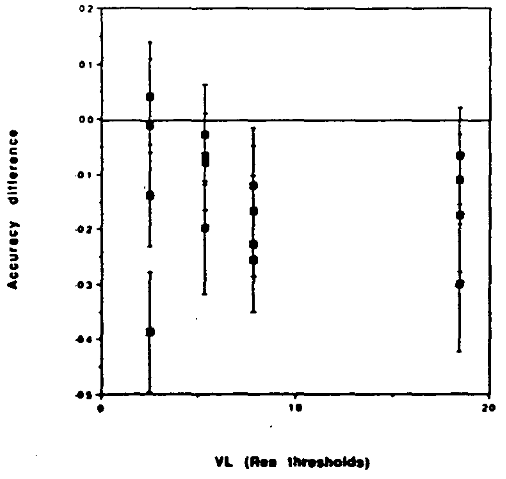


Figure 3b—Accuracy with speed instructions minus accuracy with accuracy instructions

where T is the total time after correction for marks; N is the number of glimpses (40); T_o is the nonvisual component of the glimpse duration, a is a time constant that controls how VL dynamically changes with time, V is the VL value that is needed to reach the measured accuracy, A (see **Equation 2**); and B is the collection of constants, B = (a + 0.2)/0.2.[1] We used the average value of T_o = 0.65 s from our analysis of Rea's data, and a rounded value of a = 0.2 s. To find V we approximated the log-normal formula used by Clear and Berman[1] with the basic form used by Rea, and then inverted it:

$$A = V^n/(V^n + K^n) \text{—} V = (A^{1/n}\,K)/(1 - A)^{1/n} \qquad (2)$$

This approximation has a maximum absolute difference of 1 percent, if $n = Q/\sigma$ where σ is the standard deviation of the log-normal, Q = 0.739, and $K = 10^{\alpha}$ where α is the mean of the log-normal.

The predicted times are extrapolations of the times measured in Rea's experiment to the visibility conditions used in our experiment. These values are slightly larger than those we measured when emphasizing accuracy. They are many standard deviations larger than values measured when emphasizing speed. Although not plotted here, it appears that Rea's subjects had slightly higher accuracy than our subjects, even when emphasizing accuracy. Thus it appears that the three data sets form a progression of successive tradeoffs between speed and accuracy.

Figures 3a and **3b** provide a demonstration that the instruction effect is statistically significant for both speed and accuracy. The 16 data points represent four subjects and four conditions. All 16 data points show a lower time when emphasizing speed than when emphasizing accuracy. Fifteen of the 16 points show reduced accuracy. A simple binomial probability argument shows that these trends are both significant at better than a 0.05 percent significance level.

At the highest visibilities the average time per number was 580 ± 65 ms when emphasizing accuracy, and 460 ± 30 ms when emphasizing speed. The minimum times for the four subjects were about 360–380-ms. The latter values are still larger than the 200–300-ms minimum glimpse times mentioned in the introduction. However, on pilot runs we had two subjects who averaged about 350 ms per number

Subject	VL	Instruction	Accuracy	Standard Error	Time	Standard Error
AG	2.5	Accuracy	0.871	0.060	34.47	0.73
AG	5.3	Accuracy	0.897	0.057	24.28	1.03
AG	7.8	Accuracy	0.844	0.064	25.76	0.83
AG	18.4	Accuracy	0.900	0.055	24.65	0.73
AG	2.5	Speed	0.484	0.090	26.00	0.80
AG	5.3	Speed	0.818	0.067	18.86	0.87
AG	7.8	Speed	0.724	0.083	19.45	0.53
AG	18.4	Speed	0.833	0.068	21.09	0.92
JR	2.5	Accuracy	0.333	0.086	24.66	1.41
JR	5.3	Accuracy	0.697	0.080	32.16	0.81
JR	7.8	Accuracy	0.633	0.088	27.15	1.33
JR	18.4	Accuracy	0.667	0.086	29.94	1.61
JR	2.5	Speed	0.323	0.084	21.50	1.16
JR	5.3	Speed	0.500	0.091	18.89	1.00
JR	7.8	Speed	0.406	0.087	23.31	1.17
JR	18.4	Speed	0.367	0.088	19.95	0.36
RO	2.5	Accuracy	0.788	0.071	20.47	0.48
RO	5.3	Accuracy	0.867	0.062	19.94	0.66
RO	7.8	Accuracy	0.767	0.077	20.85	0.73
RO	18.4	Accuracy	0.862	0.064	18.81	0.43
RO	2.5	Speed	0.828	0.070	18.29	0.41
RO	5.3	Speed	0.839	0.066	18.04	0.58
RO	7.8	Speed	0.600	0.089	16.59	0.50
RO	18.4	Speed	0.688	0.082	16.54	0.56
SK	2.5	Accuracy	0.897	0.057	24.97	0.64
SK	5.3	Accuracy	1.000	0.000	18.55	0.40
SK	7.8	Accuracy	0.933	0.046	23.22	0.43
SK	18.4	Accuracy	0.938	0.043	19.77	0.66
SK	2.5	Speed	0.758	0.075	17.74	0.31
SK	5.3	Speed	0.933	0.046	16.33	0.21
SK	7.8	Speed	0.677	0.084	17.03	0.31
SK	18.4	Speed	0.828	0.070	16.21	0.41
			Averaged over subjects			
group	2.5	Accuracy	0.722	0.132	26.14	2.96
group	5.3	Accuracy	0.865	0.063	23.73	3.06
group	7.8	Accuracy	0.794	0.064	24.24	1.40
group	18.4	Accuracy	0.842	0.060	23.30	2.56
group	2.5	Speed	0.598	0.118	20.88	1.90
group	5.3	Speed	0.773	0.094	18.03	0.60
group	7.8	Speed	0.602	0.070	19.10	1.54
group	18.4	Speed	0.679	0.109	18.45	1.22

Table 2—Performance data

when emphasizing speed, and had peak speeds corresponding to 250–300 ms per number. These two subjects both had accuracies comparable to those measured in the main experiment. This suggests that while glimpse duration limits speed for some subjects, the speeds for most subjects are limited by other nonvisual processes. This issue is discussed in the next section.

In addition to analyzing the data for instruction effects we also examined the data for trends in the locations or types of errors. For instance, we noticed that one subject's right hand slightly shadowed the number field. The subject was not aware of the shadow. The subject made very few errors, but the errors that he did make tended to be on the side of the number closest to the hand. There were no other obvious anomalies in the subjects' data.

We did not find any other significant trends in errors by line number, or digit location. However, there was a marginally significantly (5 percent χ^2) fewer number of misses if the mismatched digit in the right column of numbers was a zero. Subjects reported that charts with higher frequencies of zeros or duplicate digits were easier to read. We unfortunately were not set up to check the latter claim.

We did not counterbalance contrast against the other conditions, so the above trends may have affected the performance measured as a function of luminance and contrast. This is one of the reasons we did not bother to use separate T_0s for the two different luminance conditions (**Equation 1**). The data show that performance begins to degrade at the lowest visibilities, but the data are not sufficient to provide further information on the shape of the decay.

Discussion

The impetus behind this experiment was the observation that our fit to the time of the nonvisual component of Rea's experiment was surprisingly long. Our experiment indicates that subjects can speed up, but only at a loss of accuracy. As we show below, subjects' comments are consistent with the view that subjects take less time for the nonvisual components of the task when emphasizing speed.

One subject commented that he did not know what the numbers were when reading for speed, although when he spotted a mismatch he did know what the two different digits were. The information about the numbers was evidently there, but had not been brought to consciousness until a mismatch was spotted. He further noted that twice during the speed portion of the experiment he went five to ten lines past a mismatch before becoming aware of it and going back and marking it. When reading for accuracy the same subject felt that he knew what the numbers were, although he did not mentally voice the digits. When an error was found, he felt he was more likely to double-check it when reading for accuracy than for speed. However, when his data were examined for this last possibility the difference in the fitted times per mark was only 50 ms, which was not statistically significant. The same small difference and lack of significance was found for another subject who had made this same comment. One of the authors (Clear) served as a subject in a pilot run. When reading for accuracy he mentally read each of the digits. The mental voicing of the digits felt slow, but could not easily be sped up. When reading for speed Clear consciously suppressed the mental vocalization to just compare images. He did not know what the actual numbers were. This suppression felt unnatural, so speed runs tended to be a mix of visual and nonvisual comparisons. Clear's fastest runs approached 300 ms per number, which indicates that he could take close to a single fast glimpse per number.

The remaining subjects either had no comment about the difference between speed and accuracy runs except that one subject who had a much smaller differential than most could not recall any major differences. These (post hoc) comments support the notion that subjects add extra cognitive steps when reading the charts for accuracy. Although taking extra time, the steps appear to force the subject to focus on cues that might otherwise be skipped.

A consideration of the differences in performance between subjects add further weight to the notion that cognitive factors are responsible for the increase in the minimum time per number. We expected 200–300 ms but found 450 ms when reading for speed and almost 600 ms when reading for accuracy. The subject whose work is not clerical or scientific had much lower accuracies and somewhat longer times than any of the other subjects tested. This subject had no reported vision problems, and we therefore suspect that a lack of familiarity with number tasks is responsible for his poorer performance.

Subjects made a number of other comments about their runs. Several subjects stated that they preferred the gray print over the black print. On the high luminance condition the subjects as a group actually have a slightly, yet statistically significant, higher accuracy with the gray print. At low luminances the low visibility of the gray was clearly becoming a problem for some of the subjects.

One of our major themes has been the importance of duration and number of fixations required to perform a task in determining the total time to complete the task. During the course of this study, a graphic demonstration of this importance was provided by a volunteer who had had practice in stereo viewing because of amblyopia (wandering eye) as a child. The subject was tested in an informal setting without control of luminance or position. Ten test sheets were viewed normally to provide a control. On eight other test sheets she fused the two column images together by crossing her eyes. With normal viewing she read the charts with 83 percent accuracy and an average time of 25 s. For the other eight runs it took her an average of 3.2 s to achieve fusion, and another 9 s to read the charts. Her accuracy was 100 percent. Numbers that were mismatched appeared to shimmer, so it was not necessary to memorize and then recall an image. The result is that when the subject crossed her eyes she effectively saw only 20 numbers instead of 40, and spent only 450 ms per number instead of 625 ms.

The results from both the main experiment and this demonstration show that the NV task is complex. The issue of absolute performance levels is bound up in questions relating to the minimum time needed per fixation, and in questions relating to the cognitive issues of memorization, recall, and comparison, as well as questions relating to visibility.

Rea has suggested that visual performance can be fit as the product of relative visual performance (RVP) and the maximum visual performance attainable on a task.[2] He further suggested using the NV task as representative of RVP. As we have noted above, our work indicates that the NV task is much less purely visual than was believed. **Equations** 1 and 2 lead to an estimate that the visual performance of Rea's subjects varied by a factor of 30 over the range of conditions studied, while total performance only varied by a factor of 1.5. However, the practical issue is not whether we are measuring relative performance (RP) or RVP but how the two approaches differ in generalizing to other subjects, conditions, or tasks. Rea's approach for the NV task leads to the equation

$$RP \sim RVP = T(X_{max}) \times F(nv)/[T(X) \times F(nv)] \qquad (3)$$

where X and nv are the visibility and nonvisibility parameters respectively, and T and F are functions whose product has units of time. The Fs cancel in the calculation of RVP. This equation very strongly restricts the shape of the RP or RVP curve. Our approach adds a nonvisual component. The approach is not very restricting to the shape of the performance curve unless we further assume that the RVP and nonvisual components are independent. With this assumption we get

$$RP \sim [T_1(nv) + T_2(X_{max})]/[T_1(nv) + T_2(X)] \qquad (4)$$

where T_1 and T_2 are functions with units of time. The question of whether the two approaches give significantly different predictions of overall performance depends upon the task. Relative task performance on the NV task will be insensitive to changes in the nonvisual component because the latter is relatively large compared to the minimum visual component. For example, assume that one subject takes 30 s to do the task at a high visibility, and 45 s at a low visibility. If performance on the NV task is basically visual and is described by **Equation 3**, then a subject who takes 20 s at high visibility should take (45/30) × 20 = 30 s at the low visibility. If we assume instead that the minimum times are dominated by the nonvisual components and that performance is described by **Equation 4**, then the second subject should take (45 − 30) + 20 = 35 s at the low visibility. In one case RP for both subjects at low visibility is equivalent to RVP and is fixed at 0.67, while in the second case it varies from 0.67 to 0.57. This difference probably is not of great practical significance.

One can speculate from the absolute performance levels that easy reading may be a task that is considerably more sensitive to visibility than the NV task. A subject who takes only 200 ms per fixation can make 300 fixations per min. At a single word per fixation the subject will read at 300 words per min, which is a moderately fast pace. This suggests that for reasonably proficient readers the cognitive component of reading is done in parallel with the visual components. Reading faster means either reading more than one word per fixation, or skipping some words. Detection and resolution experiments show that visibility drops rapidly for objects that are not on the line of sight.[4] This implies that reading more than one word per fixation may require quite high visibilities, and thus would be even more sensitive to visibility. Because the task is different in this case, even the RVP values derived from our type of formula might be different than those derived for the NV task. On the other hand, the subject who skips words may be paying attention to the length and shape of words, and thus may be less sensitive to low visibilities than the normal reader.

A better understanding of how visibility affects overall performance requires a more comprehensive understanding of the details of task performance for each task. For example, for the NV task, we do not know if 600 ms viewing time per number represents a single long fixation, three very short fixations, or some mixture of both strategies. Similarly, it is not clear whether the improvement in detection or resolution accuracy as a function of time is due to an increased number of fixations, an increased fixation duration, or if the two are essentially equivalent.

There is also room for improvement in our modeling. Our current model for the visual component is based on data of a target presented for a limited time for which the subject has an unlimited response time. We will need data where the subject's response time is measured as a function of presentation time to better answer the question of how important luminance is to response times.[12]

Conclusion

Subjects in our experiment took about 120 ms less time per number for proofing when emphasizing speed than when emphasizing accuracy. The results show that the overall speed to perform the NV task is not determined by visibility alone. The best speeds are consistent with the idea that the subject has approximately one fixation per number. Most subjects appear to spend more than the minimum time required for a single fixation per number. We do not know if these subjects are taking long fixations, or multiple fixations. Our results indicate that even a seemingly simple task like the NV task should be analyzed in terms of total task performance instead of just visual performance. This detailed level of analysis will probably be needed for most tasks of interest to the lighting community.

Acknowledgements

This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Buildings and Community Systems, Building Equipment Division of the US Department of Energy under Contract No. DE-AC03-76SF00098. The authors would also like to thank the subjects who graciously donated their time without thought of compensation.

References

1. Clear, R. and Berman, S. 1990. Speed, accuracy, and VL. *J of the IES* 19(no. 2):124–131.

2. Rea, M.S. 1986. Toward a model of visual performance: Foundations and data. *J of the IES* 15(no. 2):41–57.

3. Salthouse, T.A., and Ellis, C.L. 1980. Determinants of eye-fixation durations. *American J of Psychology* 93(no. 2):207–234.

4. Inditsky, B.; Bodmann, H.W.; and Fleck, H.J. 1982. Elements of visual performances. *LR&T* 14(no. 4): 218–231.

5. Rea, M.S. 1981. Visual performance with realistic methods of changing contrasts. *J of the IES* 10(no. 3):164–176.

6. Smith, S.W., and Rea, M.S. 1977. *Performance of a numerical verification task under eight different light levels.* Report to the Illuminating Engineering Institute, Ohio State University, Columbus, OH.

7. Smith, S.W., and Rea, M.S. 1976. *Performance of office-type tasks under different types and levels of illumination.* Report to the Illuminating Engineering Institute, Ohio State University, Columbus, OH.

8. Commission Internationale de l'Eclairage. 1981. *An analytic model for describing the influence of lighting parameters upon visual performance.* Publication CIE 19/2.1 (TC 3.1). Paris: International Commission on Illumination.