A Hierarchy of Perceptual Training in Low Vision

J. Faubert *
O. Overbury *
G.L. Goodrich * *

*M.A. (Faubert), Ph.D. (Overbury)
Low Vision Centre
Department of Ophthalmology
McGill University, Montréal
**Ph.D.
Western Blind Rehabilitation Centre
VA Medical Centre
Palo Alto, California

1. Introduction

A growing concern in low vision care is whether people afflicted with a visual impairment can adapt to their condition and relearn to perform lost functional abilities. A purely sensory-physiological approach to this issue is restricted because 1) low vision patients often have below what is normally assumed as the basic necessary sensory input for many functional tasks (e.g. reading) and 2) in many cases, such an approach assumes a lack of plasticity past a critical period of acquisition. An alternative approach is that there is some useful plasticity or ability to relearn at all ages even though they may differ quantitatively and/or qualitatively.

> The low vision patient is often faced with the dual task of coping with the onset of visual loss and the adaptation to visual aids.

In 1950 Gibson[1] summarized many studies demonstrating that perceptual judgement tasks can be improved either by practice or training for adult observers. Other reports in the perceptual literature show that the visual system has a remarkable ability to compensate for artificially distorted images[2,3]. The low vision patient is often faced with the dual task of coping with the onset of visual loss and the adaptation to visual aids. A recent report[4] has demonstrated that an individual, restored from blindness in adulthood, can readjust and acquire limited perceptual abilities at a time in life which is long past the critical period of childhood visual development. It is also well accepted in the field of low vision, though not well researched, that some training programs can help a number of individuals to use visual aids more efficiently and perform perceptual tasks with better ease. In the late 1970's Goodrich and coworkers[5,6] demonstrated with a variety of techniques that low vision patients can use to improve the use of their residual vision.

> The question we asked was whether a hierarchical model such as the one proposed by Barraga and her colleagues has any implications for the impaired adult visual system.

Quillman *et al.*[7] demonstrated that the Frostig Figure Ground test was a useful predictor of reading efficiency. This prompted researchers from our laboratories to look into the efficiency of this test in predicting perceptual function capabilities under training and non-training conditions[8,9]. An interesting finding was that the Frostig Figure Ground was a good predictor of how well patients will adapt to their visual aids. For instance two females of the same age with visual acuities of 6/21 (20/70) in the better eye and under 6/60 (20/200) in the worse eye, who were prescribed the same correction upon a clinical assessment (+8.00 D spectacles), scored very differently on the Frostig. The one who scored best came back a few weeks later very satisfied with the prescription while the other was quite dissatisfied with the aid. A possible explanation for these results is that some kind of functional hierarchy is present where the ability to perform a "lower" level visual task is a precondition and/or a predictor of "higher" levels of visual performance.

Barraga and her colleagues[10,11] have attempted to systematize the study of visual impairment in childhood development. They proposed a hierarchy of perceptual development in the normally sighted child. They also state that the visually impaired individual follows the same pattern but is slower to progress from one level to another. The question we asked was whether a hierarchical model such as the one proposed by Barraga and her colleagues has any implications for the impaired adult visual system and whether it could explain some of the results mentioned above. To determine this the following steps are warranted. First, the development of testing and training materials which are specific to the different levels. Second, it is important to determine what level or levels of the visual hierarchy are affected by visual pathology. Thirdly, whether such a functional model is sequential in the adult system is of theoretical and practical interest. In other words, if an observer is functionally impaired at level 5, does this presuppose a functional impairment at all subsequent levels or is it level/task specific? If sequential, it is theoretically possible that training one level may improve the adjustment of subsequent levels.

Recently an attempt has been made to develop testing and training materials which represent 8 stages based on Barraga's hierarchy[12,13]. This report is a description of the testing materials developed so far and some preliminary findings. The following stages represent the hierarchy in question:

1. Visual attention: the ability to localize visual targets is tested.
2. Efficient eye movements: the patient's ability to track a moving light is tested.
3. Manipulation of concrete objects to match model: an example of this kind of task can be represented by the block

design subtest of the Weschler Adult Intelligence Scale (WAIS).
4. Copy/draw shapes from a model: stimulus configurations from the Bender Gestalt test of visual perception and similar test patterns can be used.
5. Match single element picture to complex picture: elements such as the picture completion subtest from the WAIS can be used in a modified fashion so that the test is multiple choice.
6. Figure-Ground discrimination: the baseline measure for this level is the Frostig Figure Ground test.
7. Letter and word recognition: materials have been specifically developed for the last two levels.
8. Reading efficiency.

2. Methods and Results

The first two levels of the hierarchy are essential for any progress in functional vision to occur. What is assessed by these levels is the patient's ability to perceive gross targets such as a card or bright light. On the second level a basic assessment is made of the ability of the patient to follow the target mentioned. The task does not involve sophisticated eye movement analysis such as saccades but rather the test is one of smooth pursuit. The question is whether there is enough light perception and visual stability to perform this task. The great majority of the people seen so far can perform these tasks without great difficulty. The third level is presently in development but a task such as the block design subtest of the WAIS fits the description of this level well. The unique difficulty present at this level is the concept of 3 dimensions and handling of concrete objects on several planes simultaneously. It is often the case in low vision patients that binocular vision is not the best functional vision to use. Perhaps assessment of depth perception may be required for this level.

From the third level on, many sublevels of difficulty can be envisaged in the hierarchy. For instance at the fourth level (copy/draw), the reproduction of a dot pattern (see Fig. 1) was designed along with a straight line pattern demonstrated in Fig. 2 and part of the Bender Gestalt test (see Fig. 3) has also been used.

Clearly the difficulty level is different for each test pattern. This represents one of the main difficulties in designing testing and training materials of different levels. A consensus of what is difficult or not warrants a large amount of data collection.

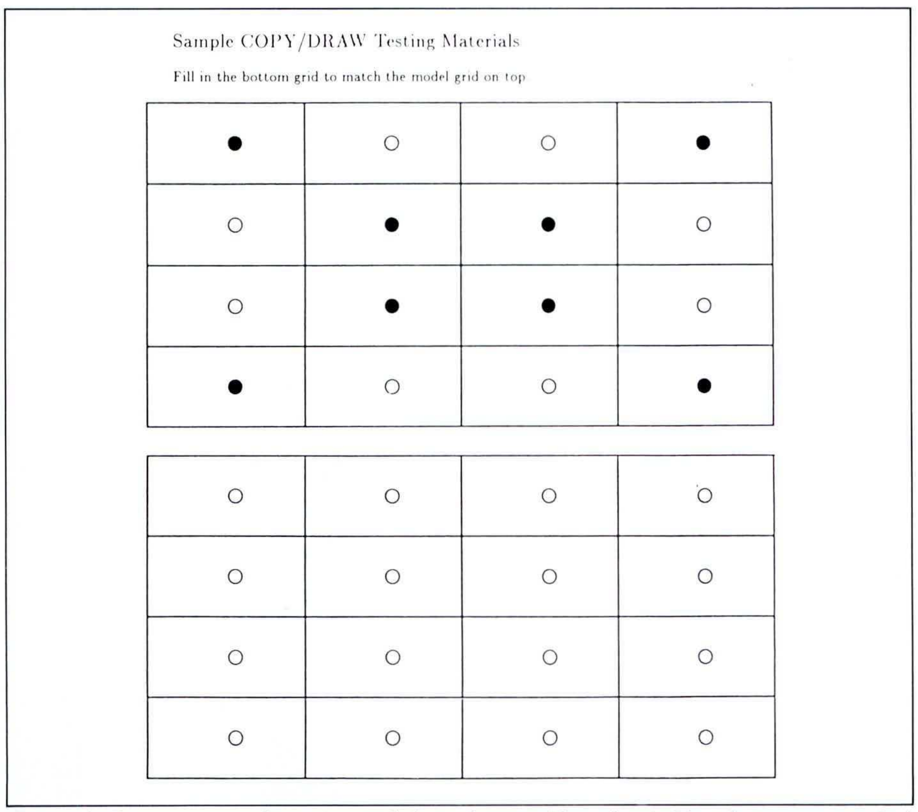

Figure 1. Dot matrix configuration task from the copy/draw level. The observers are asked to reproduce the pattern seen in the upper grid in the bottom one.

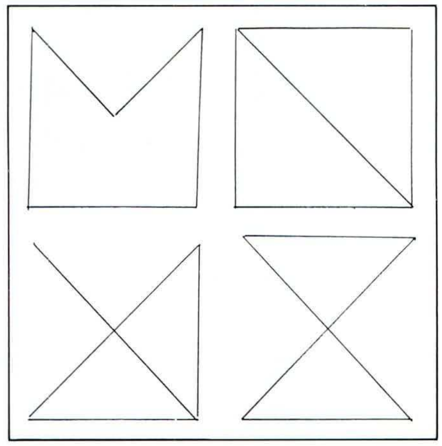

Figure 2. Straight line configuration task from the copy/draw level. The observers are asked to reproduce these 4 patterns on a separate sheet of paper.

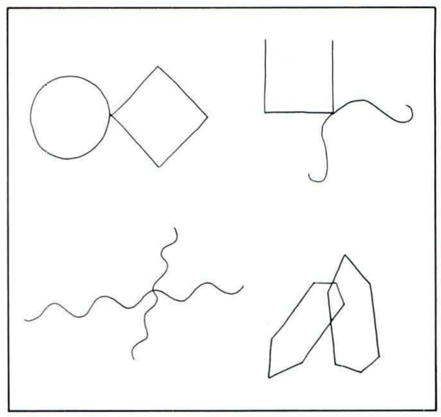

Figure 3. Bender configuration task from the copy/draw level. The observers are asked to reproduce these 4 patterns on a separate sheet of paper.

Several testing materials have been developed for the fifth stage of the hierarchy. Figures 4, 5, 6 and 7 demonstrate some of the tasks of various difficulty.

The bars test (Fig. 4) should be the easiest to perform followed by the target match (Fig. 5) and the tests derived from the WAIS picture completion test which we transformed into a multiple choice task (Figs. 6 and 7).

The sixth level inevitably involves the Frostig Figure Ground test mentioned previously. An example of a different type of figure-ground task is given in Fig. 8. This is a sample of the usual test which contains 25 numbers.

The task is to trace with a pencil from one circled number to another. At a given time the target number becomes the "figure" and the surround is the "ground". The "figure" and "ground" components in this test interchange roles during testing.

Figures 9 and 10 demonstrate letter recognition tasks and Fig. 11 is a word recognition task.

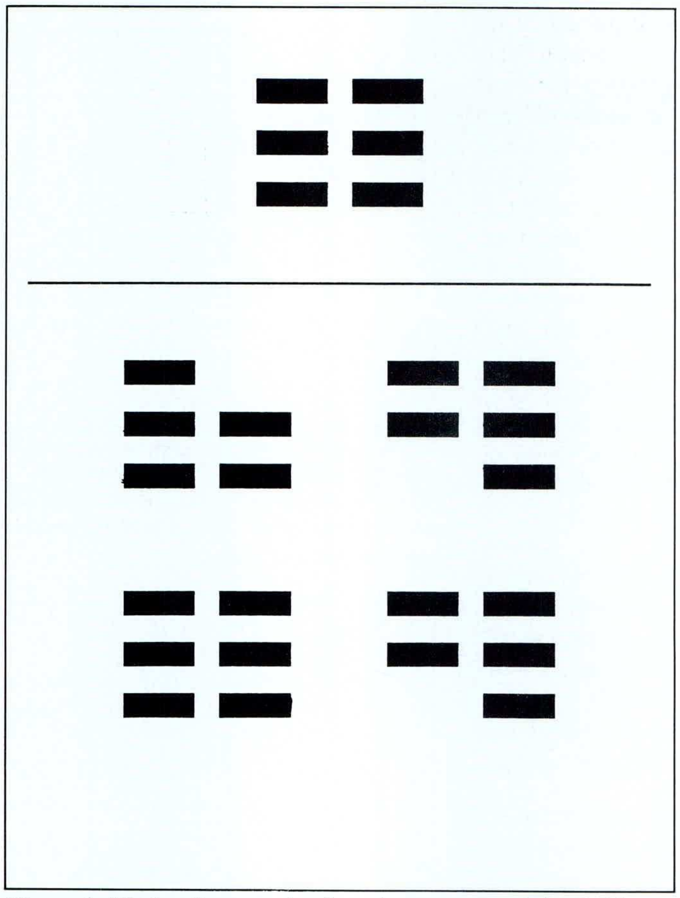

Figure 4. Missing line exercise from the target match level. The observers must identify the pattern in the 4 bottom choices which match the top pattern.

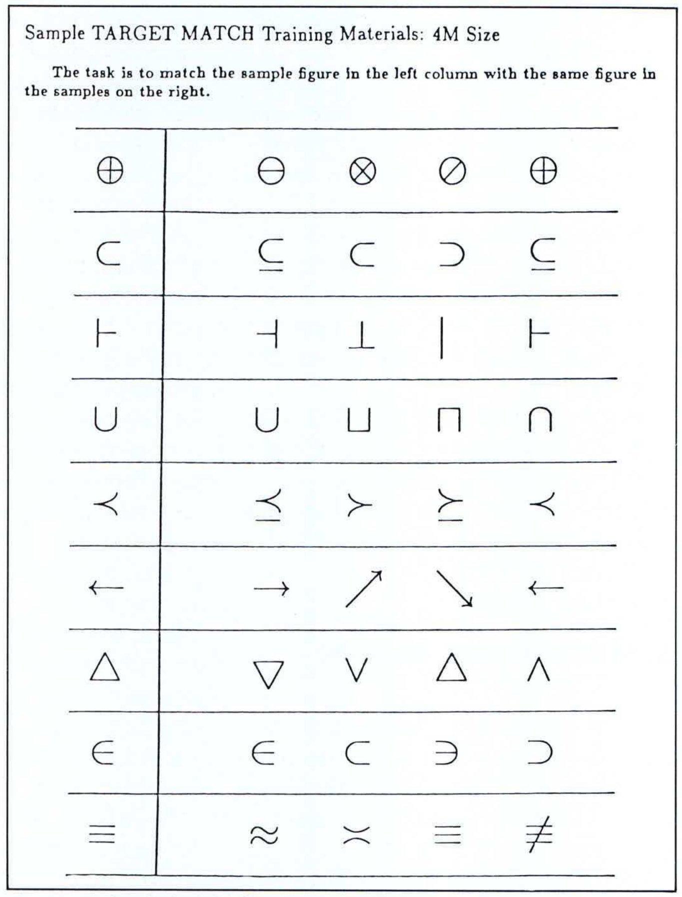

Figure 5. Symbol tasks from the target match level. The observers must identify the correct symbol in the 4 choices on the right to match the target symbol on the left (from Goodrich and Mehr[14]).

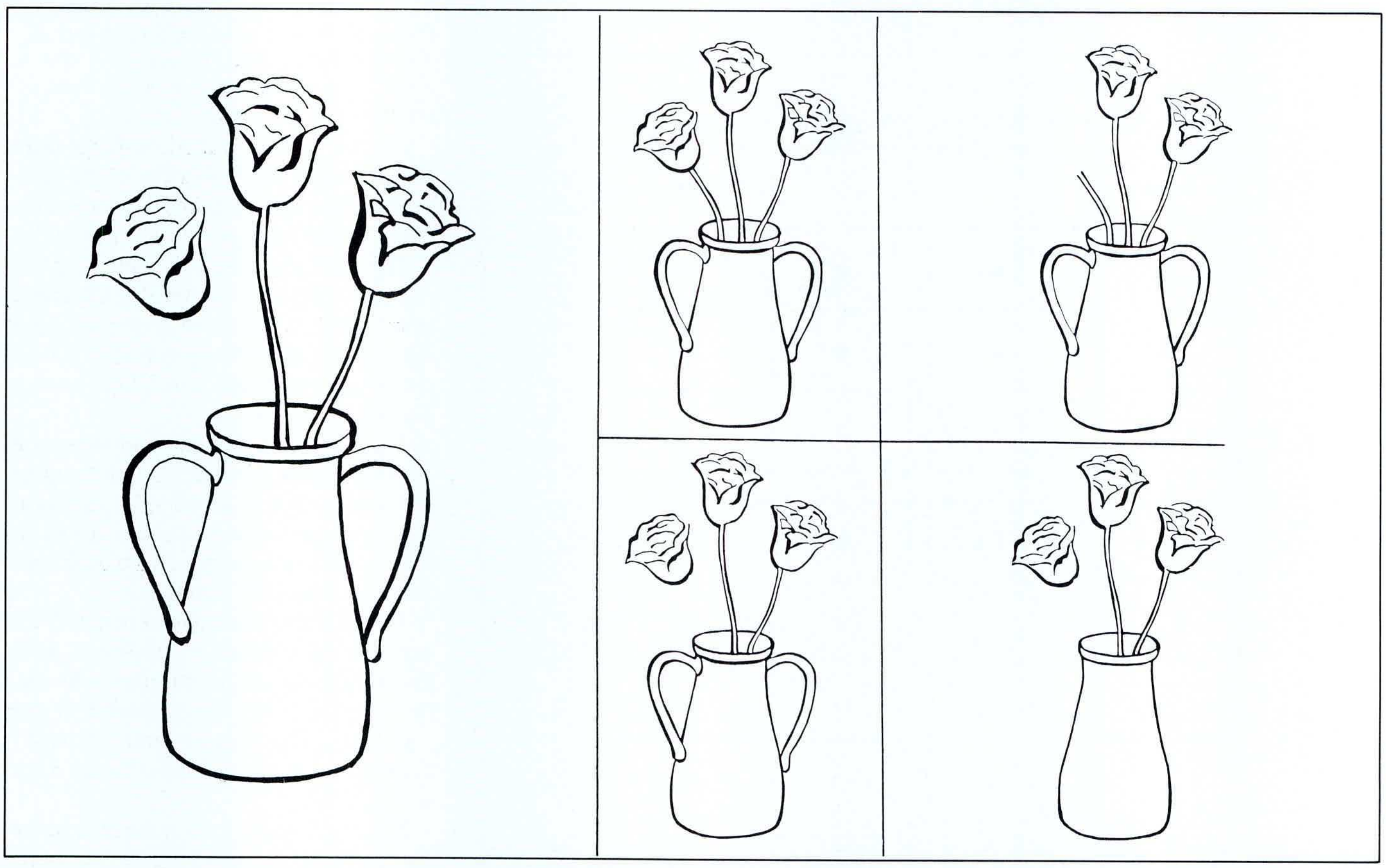

Figure 6. Flower pattern from the picture completion test (WAIS) modified to allow a multiple-choice response for the target match level.

In the letter recognition the observer is requested to identify a target letter, for example the letter "i" in Fig. 9 and "y" in Fig. 10. The word tasks require the observer to find every word in the sentence within the bottom paragraph of meaningless words (Fig. 11).

We confirmed the results obtained from previous studies stating that the Frostig Figure Ground is a good predictor of reading performance and related tasks.

Preliminary data in the form of Spearman Rho correlations of 25 patients who had completed most of these tests, demonstrate weak correlations except for the conditions of Frostig Figure Ground and all the tests in levels 7 and 8 which produced correlation coefficients between +0.56 and +0.80. In other words, we confirmed the results obtained from previous studies stating that the Frostig Figure Ground is a good predictor of reading performance and related tasks. The production of testing materials is not complete and final conclusions on the validity of each measure and how they relate is premature.

It is hoped that a systematized approach to testing and training visual functions of low vision individuals will bring about dividends in the future.

3. Discussion

Testing low vision patients with evaluative tools such as the ones just described can provide insights for future training designs on the basis of the different approaches taken by the observers. An example of this can be given by comparing the performance of two patients whom we will identify as X and Y. X and Y are both males of approximately the same age with 6/120 (20/400) in the better eye. X had a good Frostig result and Y had a bad result. The approach taken by X could be identified as "thinking his way through". When tracing a star he assumed correctly that there were so many even points and thus could trace more appropriately. It was clear that Y could not adjust to the Frostig task. When they were tested on the letter and word recognition tasks, patient Y could not do them at all. The results of patient X are demonstrated in Figs. 12, 13, 14 and 15.

A demonstration of his strategy for identifying the "y"'s was shown to us by the patient and can be seen in Fig. 14. He would look for the "tail end" of the "y" which was very different from the "g". In the word recognition task it is clear from Fig. 14 and 15 that patient X was tracing from one consonant to the other such as a "d" and a "t", to determine the correct word. For example, when searching the word "doesn't" in the phrase, a horizontal line was drawn between the "d" and "t" of "don't" and "doesn't" which, by the difference in length, helped recognition of the appropriate word. X also was able to read the standard text in 9 minutes and 31 seconds.

What this tells us is that 1) an individual who theoretically should not have been able to read was able to do so with highly strategic maneuvers, and 2) training observers to be more attentive to pattern details of words may enhance their performance. Ideally, after systematic training this could become second nature and not necessitate conscious attention on the part of the reader.

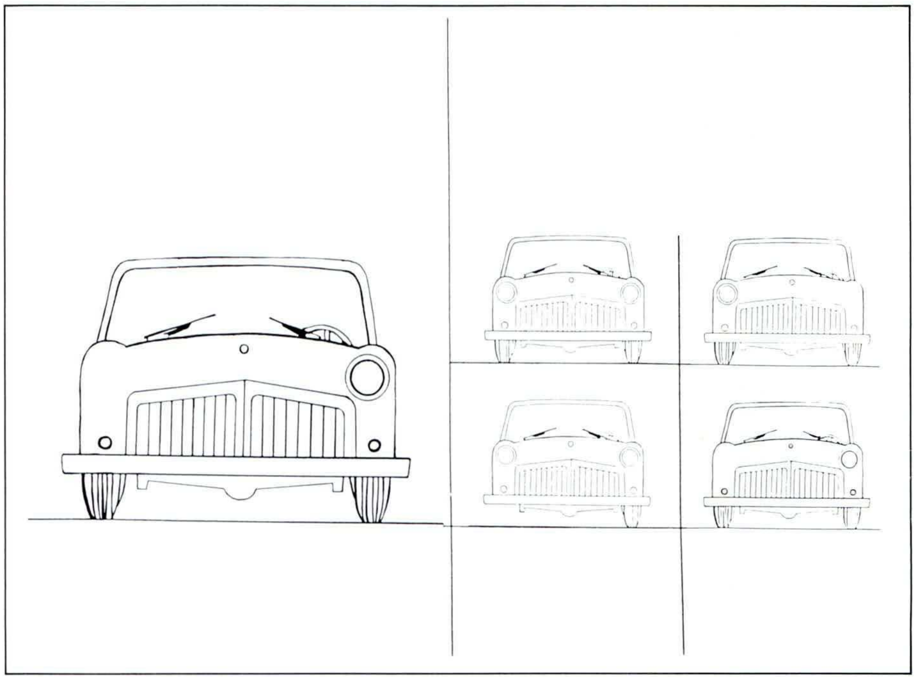

Figure 7. Car model from the picture completion test (WAIS) modified to allow a multiple-choice response for the target match level.

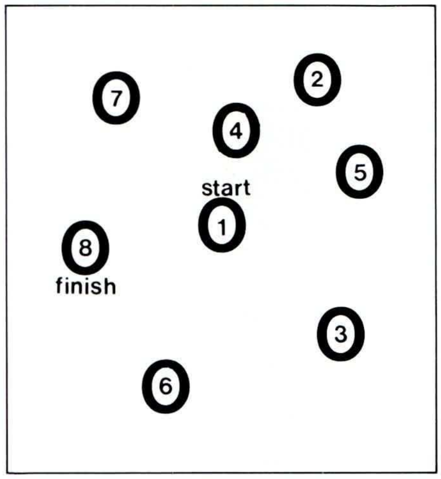

Figure 8. Sample of tracing number task for the figure-ground level. The observer must trace from one number to another. The actual test contains 25 numbers.

An attempt was made to describe the ongoing activities of a long term joint project between two low vision service centers. It is hoped that a systematized approach to testing and training visual functions of low vision individuals will bring about dividends in the future. This would enable related professionals to understand the dynamics of low vision and to speak "the same language" and thus improve services in this area.

4. References

1. E.J. Gibson: Improvement of perceptual judgements as a function of controlled

Patient Name or Code: ____________________ Date: __________

Low Vision Clinic (check 1):

[ ] Palo Alto [ ] Berkeley [ ] Houston [ ] New York [ ] Montreal

Find the "i's":

llllll lllll lilll llll llllil llli illll llill llll llil
llill lllll lll llllll lill lllill lll lllill lll lllll
lll ill llllil llll lilll llll lllll lill llll llli llll
lillll llill lllll llllil llll llli lllll llll illll lll

Number of "i's" found: __________

Time to complete: __________

Comments:

Figure 9. Example of letter search task. Observer must identify the "i"s embedded within the "l"s.

Patient Name or Code: ____________________ Date: __________

Low Vision Clinic (check 1):

[ ] Palo Alto [ ] Berkeley [ ] Houston [ ] New York [ ] Montreal

Find the "y's":

ggggygg gggg ggy gggg ggygg ggyggg
gyggg ggy gggggg gyggg gggygg gggg
ggggg gygg gyggggg ggggy gyg ggggg
gggg gggggy gygg gggygg gggg gyggg

Number of "y's" found: __________

Time to complete: __________

Comments:

0.2in

Figure 10. Letter search task where the observer must identify the "y"s embedded within the "g"s.

Get some extra milk, eggs, and fish when you shop today.

Got Get Go gone some soon extra exert melt milk malt eyes eggs east and end fish fine what where when you year shop ship today toast

Min ___ Sec ___

Jack, who always cries, and his friend, who doesn't, were lost.

Jack Joke Jake who why how away always after cry cries crisis and this her his kind friend find who don't doesn't where were last lost

Min ___ Sec ___

Figure 11. Example of word search task. The observer must identify the words in the nonsense paragraph below which make up the target sentence.

Patient Name or Code: ____________________ Date: __________

Low Vision Clinic (check 1):

[ ] Palo Alto [ ] Berkeley [ ] Houston [ ] New York [ ] Montreal

Find the "i's":

llllll lllll lilll llll llllil llli illll llill llll llil
llill lllll lll llllll lill lllill lll lllill lll lllll
lll ill llllil llll lilll llll lllll lill llll llli llll
lillll llill lllll llllil llll llli lllll llll illll lll

Number of "i's" found: __________

Time to complete: __________

Comments:

Figure 12. Results of patient X in the "i" letter search task.

Patient Name or Code: __________ Date __________
Low Vision Clinic (check 1):
[ ] Palo Alto [ ] Berkeley [ ] Houston [ ] New York [ ] Montreal

Find the "y's":

ggggygg gggg ggy gggg ggygg ggyggg
gyggg ggy gggggg gyggg gggygg gggg
ggggg gygg gygggggg ggggy gyg ggggg
gggg gggggy gygg gggygg gggg gyggg

Number of "y's" found: __________ y) 888

Time to complete: __________

Comments:

0.2in

Figure 13. Results of patient X in the "y" letter search task.

Dad, who made the fire, needs two or three more logs.

Babs Dad who how mode made
the there firs fire feeds seeds needs
trees to two or are and four
three move sore more kegs logs

Min __ Sec __

Figure 15. b) Results of patient X in the word search task.

Get some extra milk, eggs, and fish when you shop today.

Got Get Go gone some soon extra
exert melt milk malt eyes eggs east
and end fish fine what where when
you year shop ship today toast

Min __ Sec __

Jack, who always cries, and his friend, who doesn't, were lost.

Jack Joke Jake who why how away
always after cry cries crisis and
this her his kind friend find who
don't doesn't where were last lost

Min __ Sec __

Figure 14. a) Results of patient X in the word search task.

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