Department of Veterans Affairs

JRRD Volume 41, Number 2, Pages 233–242
March/April 2004
Journal of Rehabilitation Research & Development

Use of Rasch person-item map in exploratory data analysis: A clinical perspective

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Abstract—The National Institutes of Health (NIH) includes visual impairment in the 10 most prevalent causes of disability in America. As rehabilitation programs have the potential to restore independence and improve the quality of life for affected persons, NIH research priorities include evaluating their effectiveness. This article demonstrates a clinical perspective on the use of the Rasch person-item map to evaluate the range and precision of a new vision function questionnaire in early analysis (prior to full sample). A self-report questionnaire was developed to measure the difficulty that persons with different levels of vision loss have performing daily activities. This 48-item Veterans Affairs Low-Vision Visual Functioning Questionnaire (VA LV VFQ-48) was administered to 117 low-vision patients. Preliminary analysis indicates that the questionnaire items are applicable to persons of differing abilities. The Rasch person-item map demonstrates that the field-test version of the VA LV VFQ-48 has good range and is well centered with respect to the person measure distribution. Construct validity and reliability are also demonstrated.

Key words: Rasch analysis, low-vision rehabilitation, outcomes measurement.

INTRODUCTION

The National Eye Institute (NEI) defines low vision as “chronic visual deficit that impairs everyday function and is not correctable by ordinary spectacles or contact lenses [1].” Visual impairment is included as one of the 10 most prevalent causes of disability in Americans [1].

Abbreviations: HRQL = health-related quality of life, NEI = National Eye Institute, VA = Department of Veterans Affairs, VA LV VFQ-48 = VA Low-Vision Visual Functioning Questionnaire.

This material was based on work supported in part by the Department of Veterans Affairs Rehabilitation Research and Development Service, the Illinois Society for Prevention of Blindness, the Massachusetts Eye and Ear Infirmary Joel A. Kraut Teaching and Research Fund, the Max Goldenberg Foundation, and Research to Prevent Blindness, Inc.

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The association between age and visual decline is well established [2]. Estimates are that more than two-thirds of those with low vision are 65 years or older [1]. Given the universality of population aging and the expected growth in the number of seniors as the baby boom generation reaches age 65, projections are that by 2030 there will be as many as 68 million Americans over the age of 65 [1]. With increased longevity, the relationship between societal cost and quality of life for older persons is a dominant issue in healthcare delivery, particularly in view of mounting bills for healthcare of the elderly.

The leading causes of low vision are age-related macular degeneration, glaucoma, diabetic retinopathy, and optic nerve atrophy [1]. These diseases are most prevalent in the elderly population. While there has been considerable progress in the treatment of eye disease, there are no cures available for most of the diseases causing age-related vision loss. Many Americans are living with chronic visual impairments, regardless of access to the best medical treatment available.

Chronic visual impairments can have a profound effect on the lives of individuals, restricting self-sufficiency and independence by reducing their abilities to read, perform activities of daily living, travel from place to place, and interact with family and friends [3]. Effective and efficient methods of visual rehabilitation for people with low vision are required to meet the needs of this expanding disabled population. NEI has identified the need for research to provide a clearer understanding of the effects of visual impairment on everyday activity performance and to evaluate the effectiveness of rehabilitation of the visually impaired [1]. Valid and reliable measurement tools are needed to meet all these objectives.

Evaluation of low-vision and blind rehabilitation services is of primary importance to the Department of Veterans Affairs (VA), as estimates are that there will be 854,000 severely visually impaired veterans in the year 2005 and 890,000 in the year 2010 [4]. The most recent statistics, based on the 2000 census, suggest that it will be well into the next decade before the number of severely visually impaired and legally blind veterans begins to decrease [5]. The VA is struggling to provide the highest quality healthcare for our nation's veterans in a cost-effective manner, with fewer dollars of financial support.

The low-vision rehabilitation process begins with assessment of remaining vision, attitudes toward vision loss, and psychological well-being. Each patient's perception of his/her functioning at home, at work, and in the community is ascertained through an extensive patient history. During the low-vision examination, clinical tests of visual acuity and visual field are performed to assess the extent of visual impairment. Because patients with the same level of visual impairment may function quite differently, knowledge of the difficulties encountered and perceived priorities is required to establish goals for an individual rehabilitation plan. A questionnaire that captures the patient's self-report of difficulty performing activities at the initial interview, and any subsequent changes in difficulty performing these activities after rehabilitation, would be useful to ensure that all relevant issues are covered and that each patient's needs have been met by the rehabilitation program. Such an instrument would provide a functional profile of the patient that cannot be captured by the clinical tests of visual acuity or visual field. This assessment tool would also promote cost-effective service delivery by providing outcome measures relevant to the goal of the rehabilitation program and to the types of services provided.

Our goal is to develop an accurate and sensitive evaluation tool for vision rehabilitation. To be a valid measuring tool, our instrument must be held to the same standards as physical measures of weight and length. Once a yardstick is calibrated, it serves as a standard that does not change, whether we measure the length of a chair or a table. The underlying principle is that a measure must be independent of the observer and not dependent on the objects or subjects selected for measurement [6]. Once calibrated, our scale should measure visual ability independent of the study subjects in the sample we are using.

A vision function questionnaire can be compared to a visual acuity chart that is used to measure one's ability to resolve visual detail. Large letters are located at the top of the acuity chart. As we move down the chart, the letters decrease in size and become more difficult to read. If the eye chart has a large range of letters with small steps in letter size between lines, visual acuity can be measured with precision on patients with a wide range of visual impairments. Because a vision function questionnaire uses ability to perform specific tasks rather than letters, it is important that the scale be calibrated to have a range large enough to measure all persons who have vision loss. In order to make precise measurements, the measurement error and intervals between task difficulties must be small.

Maps produced by the Rasch statistical method can be used to communicate complex information quickly and in a presentation format that is easily understood. This article presents a clinical perspective on the use of the Rasch analysis to perform preliminary data analysis (prior to full sample) to evaluate the range and precision and construct validity and reliability of the 48-item field-test version of the VA Low-Vision Visual Functioning Questionnaire (VA LV VFQ-48).

METHODS

Instrumentation

During the past decade, there has been considerable emphasis on health-related quality of life (HRQL) [7]. General or disease-specific instruments measure a patient's own perception of health and ability to function as a result of disease and health status. Although some single instruments measure multiple dimensions of quality of life, the current trend is to use a "battery approach," in which the various components of HRQL are measured with different scales to ensure a comprehensive assessment of each domain [8]. For this reason, the research team developing the VA LV VFQ-48 elected to focus on developing a visual ability scale that could be combined with existing instruments to measure the HRQL of persons with permanent vision loss rather than developing a single instrument to measure HRQL.

Item content for the VA LV VFQ-48 was chosen after a review of discipline-specific clinical guidelines for optometry, ophthalmology, occupational therapy and blind rehabilitation, consensus panel recommendations on skills veterans should develop in VA blind rehabilitation programs, previous publications by the authors, and structured interviews with patients to determine their interest in obtaining low-vision devices to perform daily activities [9–22]. A modified Delphi method was used to develop consensus between investigators, the research coordinator, and Hines VA visual skills instructors [9].

The Delphi method of survey research developed by Rand Corporation requires repeated surveying on the same issue or problems so that respondents can come to an informed consensus [23]. Whereas Rand used written surveys, we have modified the method, using the technique to include interviews with patients and staff rather than written questionnaires. The initial draft, developed in round 1 of the modified Delphi method, was field tested in individual interviews at the Hines VA Blind Rehabilitation Center (Hines IL) with 20 patients and 5 visually impaired staff, to identify problems in wording or item order. In round 2 of the modified Delphi method, 48 items were selected for the initial field-test version of the VA LV VFQ-48. The items vary in difficulty from easy to impossible to perform for persons with visual acuity, visual field, and/or contrast sensitivity deficits. Activities performed at far, intermediate, and near distances, both at home and in the outside community, are included. Although similar items are found on other questionnaires, item descriptions are condensed and simplified to be user-friendly for older persons. Identical response scales are used for all items to simplify the task of completing the survey and to decrease administration time.

For each of the 48 tasks listed in the **Figure 1**, patients are asked how difficult it is to perform the tasks with conventional glasses/contact lenses, low-vision devices, or adaptive techniques.

The five response choices are not difficult, slightly difficult, moderately difficult, extremely difficult, or impossible. Items were scored from 1 to 5, with not difficult = 1 and impossible = 5. If difficulty is reported, patients are asked whether the difficulty is due to vision loss. Items are not scored if the difficulty is not due to vision loss or if the patient does not perform the activity.

Subjects

Subjects included 117 low-vision patients representing the continuum of vision loss from near normal distance vision to no light perception (mean visual acuity 0.73 LogMar, with a standard deviation of 0.33). There were 96 men and 21 women, mean age 72 years (range 29–93). The distribution of diagnoses was as follows: age-related macular degeneration, 47 percent; glaucoma, 11 percent; diabetic retinopathy, 9 percent; and other, 32 percent. Patients were recruited who were scheduled to participate in low-vision rehabilitation programs at the Hines VA Blind Rehabilitation Center; the Chicago VA Health Care System, West Side Division, Visual Impairment Center to Optimize Remaining Sight (Chicago); the Vision Rehabilitation Center, Massachusetts Eye and Ear Infirmary (Boston); and the Edwin and Lois Deicke Center for Visual Rehabilitation (Maywood, IL). The field-test version of the VA LV VFQ-48 was administered by telephone to these patients before they began rehabilitation. All English-speaking subjects that could be reached by telephone were invited to participate. Informed consent

How difficult is it to: ____? Response choices, scored 1 to 5: (1) Not difficult, (2) slightly difficult, (3) moderately difficult, (4) extremely difficult, (5) impossible

1. Get dressed
2. Keep clean
3. Identify medicine
4. Tell time
5. Identify money
6. Match clothes
7. Groom self
8. Identify food on a plate
9. Eat/drink neatly
10. Fix a snack
11. Prepare meals
12. Use appliance dials
13. Clean the house
14. Handle finances
15. Make out a check
16. Take a message
17. Find something on a crowded shelf
18. Find public restroom
19. Get around indoors in places you know
20. Get around outdoors in places you know
21. Get around in unfamiliar places
22. Go out at night
23. Get down steps in dim light
24. Adjust to bright light
25. Cross streets at a traffic light
26. Use public transportation
27. Get around in a crowd
28. Avoid bumping into things
29. Recognize persons up close
30. Recognize persons across the room
31. Read street/store signs
32. Read headlines
33. Read menus
34. Read newspaper/magazines
35. Read mail
36. Read small print on packages
37. Read print on TV
38. Keep your place while reading
39. Watch TV
40. Play table and card games
41. See photos
42. Work on your favorite hobby
43. Go to movies
44. Go to spectator events
45. Play sports
46. Do yard work
47. Sign your name
48. Read signs

Figure 1.
VA LV VFQ-48 task list with items abbreviated on person-item map in bold print.

was obtained according to institutional review board requirements.

Analysis

Our research to develop the VA LV VFQ-48 relied heavily on the use of the Rasch rating scale model to estimate measurements from subjects' ratings of the difficulty they have performing activities [24]. Rasch analysis was first introduced to the low-vision and blindness field in 1985 with the work of Schulz and his colleagues in the evaluation of the Hines VA Blind Rehabilitation Center program [25]. Their work represented a major paradigm shift for healthcare outcome research in general, not just for clinical vision research. The prevailing practice in clinical vision research had been to assign numerical scores to the response choices and to add the scores together to determine an overall score for the questionnaire [26]. Addition of these scores is only justifiable when the scores represent an interval scale [6]. The VA LV VFQ-48 uses a Likert-type scale. Likert scales present an observation or a question with several response choices based on the level of agreement (or, here, difficulty) [6]. In the case of the VA LV VFQ-48, the question is, how difficult is it to perform specific daily activities. The responses are not difficult, slightly difficult, moderately difficult, extremely difficult, or impossible. Because the levels of difficulty that patients have performing the activities on the survey are ordinal ratings, not equal intervals, we use the Rasch model to convert our ordinal data to interval scales. Otherwise, we would not be able to interpret the size of the differences between people in their visual ability scores [6].

Early analysis (prior to full sample) was conducted on data from the first 117 subjects interviewed. Our purpose in conducting the preliminary analysis was to look at the measurement properties of our scale to determine (1) the range of the scale (if the activities we have chosen vary in difficulty from easy to difficult), (2) the precision of the scale (if the activities selected allow us to discriminate persons with different levels of visual ability), and (3) if the scale is valid and reliable. Considering the costs and time required for data collection, we wanted to make major revisions to the instrument before we collected data on the full sample of subjects if serious problems with our measurement instrument were identified in the preliminary analysis.

The BIGSTEPS program was used to estimate the perceived visual ability for each person and the required visual ability for performance of the 48 tasks [27]. We expected an inverse relationship between perceived visual ability and difficulty performing the daily activities that were selected for the questionnaire. Persons with less visual ability should have a high probability of reporting difficulty performing tasks, and those with more visual ability should have a low probability of reporting difficulty performing the same tasks.

RESULTS

The Rasch person-item map displays a ruler created from the measurements of patients' abilities to perform activities of daily living and the visual ability needed to perform each activity. The Rasch person-item map shown in **Figure 2** orders the level of self-reported visual ability of the patients in our study (left side) and the difficulty of the activities (right side). Activities at the top of the scale are easier to perform. Activities become more difficult to perform further down the scale. Subjects with the least visual ability (at the top of the scale) have difficulty even with the easiest activities; subjects with more visual ability (at the bottom of the scale) have no difficulty performing any of the activities.

The visual ability of each person to perform activities is referred to as the person measure, and the visual ability required to perform each item with a criterion level of difficulty is called the item measure [26]. We examined the map of persons and items to compare the range and position of the item measure distribution (left side of **Figure 2**) to the range and position of the person measure distribution (right side of **Figure 2**). Items should be located at each point on the scale to measure meaningful differences. The items must cover all the areas on the ruler if we are to measure the visual ability of all persons. On our scale, the distance of the item from the top of the ruler correlates to its difficulty relative to the other items. Items closer to the top are easier to perform; moving down the scale, the items become more difficult—that is, they require greater amounts of visual function. The activities at the top of the person item map—get around indoors in places you know, keep clean, and get dressed—require the least visual ability (i.e., they are the easiest). Reading small print on package labels, playing sports, and reading newspaper/magazine articles are located at the bottom of the scale. They require the most amount of ability (i.e., are the hardest). Intuitively, this makes sense, as the letters used for newsprint are equivalent to 20/40 letters on a visual acuity chart. The visual challenge to see grosser objects of clothing should be considerably less. The items we have selected cover most persons on the scale; only a few persons with a very high level of visual ability will find no corresponding items.

Validity

It is not enough to only estimate the person and item measures; it is also necessary to evaluate the validity and reliability of those estimates [15]. Validity refers to the accuracy of the measurement [6]. In other words, we want to know how well the Rasch model can predict the response of each patient to each item. Fit statistics are used to test the validity of the estimated measures. The difference between the response expected by the model and the observed response is called a residual [6]. The fit statistics are normalized mean squared residuals (across items for each person or across persons for each item). These mean-square fit statistics are reported in two different ways, infit and outfit. Outliers, data points that are not typical of the rest of the values, will influence the mean difference between observed and expected values. If we exclude the outliers, we expect to see less difference than if they are included in our examination of the data. The

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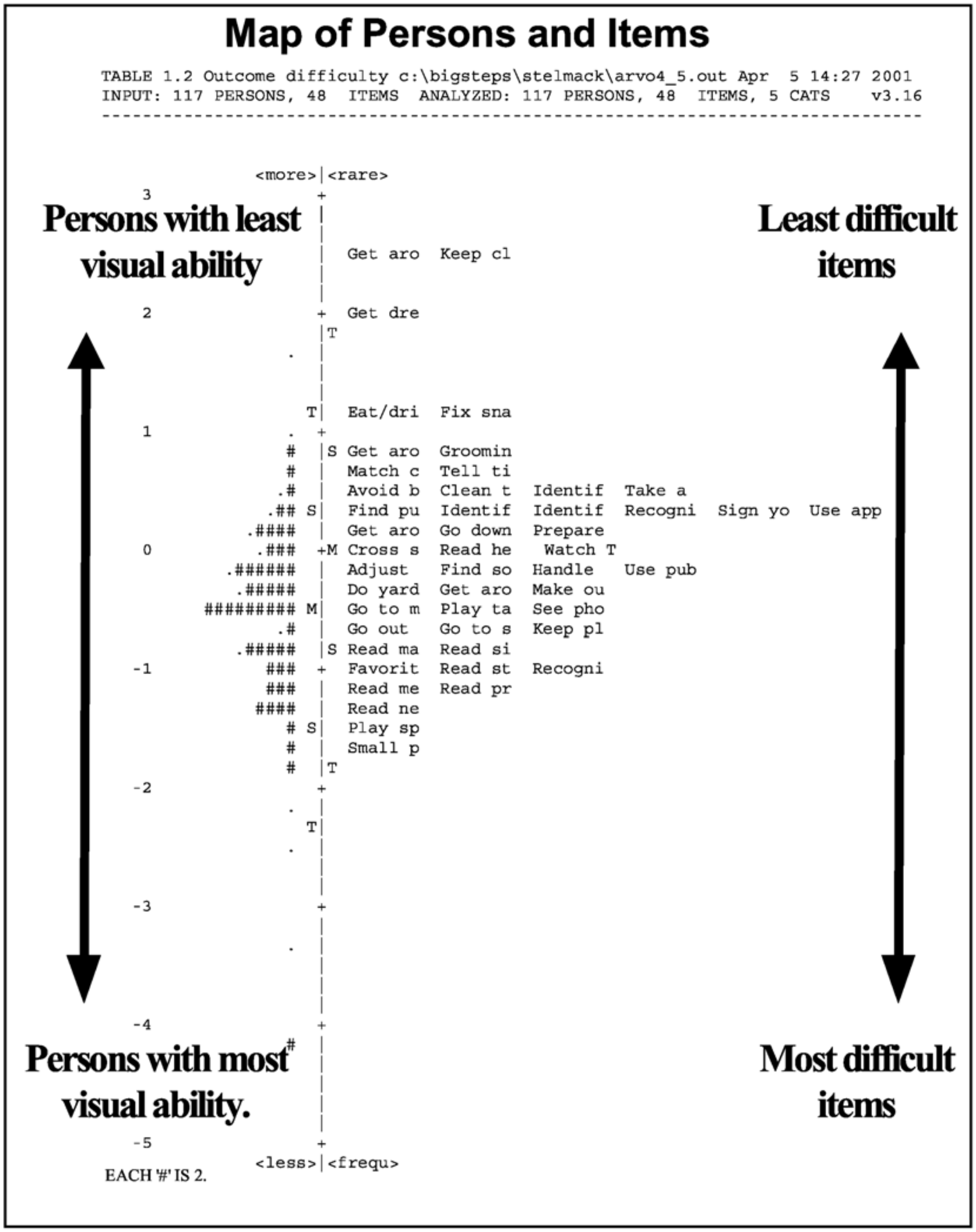

Figure 2.
Map of persons and items.

outfit statistic (outlier-sensitive fit statistic) reflects large differences between observed and expected values for items that are far from the person's ability [6]. The infit statistic (information-weighted fit statistic) emphasizes residuals for items that are close to the person's ability [6]. If the error is random, the mean-square residuals are expected to be distributed as ^{2}. Therefore, the mean-square residuals are transformed so that the expected ^{2} distribution is a standard normal distribution, with an expected mean of 0 and an expected standard deviation of

The transformed fit statistics are considered to be consistent with the expectations of the model if their distribution agrees with the expectations of the standard normal distribution (i.e., within ±2 standard deviations of the mean). We have plotted the outfit versus infit for the questionnaire items used in the question “how difficult is it to?” in **Figure 3** so the reader can easily identify the items (outlined by the polygon) that do not fit the expectations of the model. The misfitting items, located in the polygon, are outside the standard normal distribution. They contribute minimal information to the measurement properties of the scale.

For the data presented here, 7 out of 48 items had mean squares that exceeded the expected value by more than 2 standard deviations (handle finances, work on your favorite hobby, keep place while reading, adjust to bright light, use public transportation, get around indoors in places you know, and go out at night). For our data, 4 percent of the persons had mean squares that exceeded the expected value by more than 2 standard deviations (approximately 2.5% would be expected to exceed 2 standard deviations by chance alone). Analysis of the mean-square fit statistics indicates that the estimated measures are valid.

Reliability

Reliability refers to the percentage of observed responses that are reproducible. The reliability is estimated for both persons and items. The person measure reliability estimates how well we can discriminate people based on their estimated visual ability [6]. The item measure reliability indicates how well items can be discriminated from one another on the basis of their difficulty [6]. Reliability ranges from 0 to 1.0. The closer the reliability is to 1.0, the less the variability of the measurement can be attributed to measurement error. For the present data, the item measure reliability is 0.97 and the person measure reliability is 0.94. These results indicate that the estimated measures are highly reliable (i.e., 3% and 6%, respectively, of item and person measure variability can be attributed to measurement error).

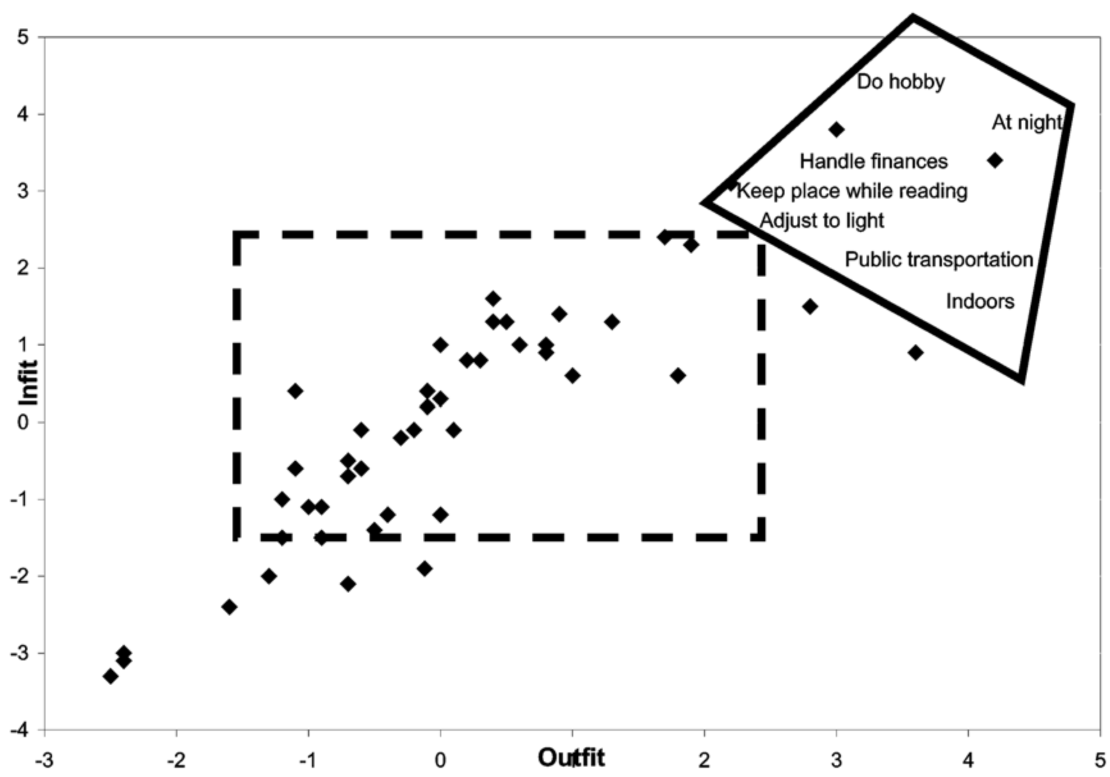

Figure 3.
Relationship of outlier-sensitive fit statistic (outfit) versus information-weighted fit statistic (infit) for questionnaire items: is it difficult to: ____?

DISCUSSION

The map of persons and items demonstrates that the VA LV VFQ-48 has good range and is well centered with respect to the person measure distribution. The persons are distributed from most to least disabled, as would be expected from a sample of subjects with visual impairment that varies from no light perception to near normal vision. The items selected are adequate to describe the functional ability of the subjects in the study, because there is at least one item for all but one level of difficulty on our scale and as many as six items for some levels of difficulty.

In cases where there are multiple items representing the same level of difficulty, some of these items could be omitted to shorten the questionnaire. As only 7 out of 48 items exceeded the expected value by more than 2 standard deviations, there are a number of items to choose from in finalizing the instrument. The seven items that misfit (handle finances, work on your favorite hobby, keep place while reading, adjust to bright light, use public transportation, get around indoors in places you know, and go out at night) may say more about preferences in lifestyle of older patients than visual functioning, or they may have multidimensional interpretations. The items of get around in places you know, keep clean, get dressed, eat and drink neatly, and fix a snack are probably too easy for even the most disabled patients, as hardly anyone reports difficulty with them. These items also could be removed, as they do not add any visually relevant information about the people we are measuring.

We also note that some patients do not have difficulty performing any items. We could consider adding a more difficult item, although the item reading small print on a package label is visually quite challenging. Items such as driving in poor weather conditions, driving in heavy traffic, or driving at night may also be used to expand the scale. However, most legally blind patients have stopped driving, and we would anticipate few responses to these items. The Rasch person-item map alerts us to the strong possibility of a ceiling effect: the questionnaire cannot distinguish among persons with high levels of visual function, most likely those with near-normal vision. However, this is not our goal in developing a low-vision questionnaire. Currently, we are administering the VA LV VFQ-48 to a larger cohort of patients before and after completion of their rehabilitation programs. We suspect that we will not measure significant change after rehabilitation for the highest functioning patients with this instrument. Floor and ceiling effects, as well as item reduction to shorten the instrument, will be explored further when the full data set from administration of the VA LV VFQ-48, pre- and post-rehabilitation, is evaluated. While we are hesitant to make any substantial changes in the instrument at this time, we have shown that the initial field test version of the VA LV VFQ-48 demonstrates appropriate range and precision and construct validity and reliability in the preliminary analysis.

ACKNOWLEDGEMENTS

The authors wish to thank Benjamin D. Wright, PhD, for his contribution to questionnaire development and data analysis; and Ziba Ardickas, Barbara Cooper, Melinda Dunlop, Mark Kuzia, Barbara Miller, Dani Moran, and Donna Vincent for data collection. Funding for this study came from the VA Rehabilitation Research and Development Service, the Illinois Society for Prevention of Blindness, the Massachusetts Eye and Ear Infirmary Joel A. Kraut Teaching and Research Fund, the Max Goldenberg Foundation, and Research to Prevent Blindness, Inc.

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Submitted for publication January 6, 2003. Accepted in revised form June 24, 2003