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Psychometric properties of visual functioning index using Rasch analysis

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ABSTRACT.
Purpose: **The visual functioning index (VFI) was one of the first questionnaires developed using classical test theory to assess outcomes of cataract surgery. However, it was not Rasch-validated. The objective of this study was to examine the psychometric properties of the VFI using Rasch analysis in patients with cataract.**
Methods: **The 11-item VFI was self-administered to 243 patients (mean age 73.9 years) drawn from a cataract surgery waiting list. We examined the response category thresholds, item fit statistics, differential item functioning and unidimensionality for the VFI and its three subscales.**
Results: **Category thresholds were ordered. The person separation and reliability were low, indicating the poor discriminatory ability of the VFI. No items misfit but there was suboptimal targeting of item difficulty to patient ability. On the whole the items in the VFI were too easy for the sample. Only one item showed moderate differential item functioning.**
Conclusion: **The VFI does not meet the stringent requirements of the Rasch model. However adding more items to suit the more able patients with cataract as well as those awaiting second-eye cataract surgery could optimize the VFI.**

Key words: cataract – cataract surgery – classical test theory – Rasch analysis – visual functioning index

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Introduction

Coinciding with an ageing population, cataract extraction has become the most performed surgical procedure in Australia. Patient concern is the strongest predictor of referral for cataract surgery by Australian ophthalmologists (Keeffe et al. 1996; McCarty et al. 2000) . There is now ample evidence to show that visual function before surgery is the strongest predictor of visual outcome and quality of life after surgery, independent of visual acuity (Elam et al. 1988; Brenner et al. 1993; Mangione et al. 1994; Schein et al. 1995). Patient-reported outcomes (questionnaires) are valuable to assess visual functioning because they provide information unavailable from clinical evaluation (Mangione et al. 1992; Steinberg et al. 1994; Pesudovs et al. 2003, 2004; Pesudovs, 2006).

Few questionnaires used previously to assess visual disability in cataract patients [e.g. visual function-14 (VF-14; Steinberg et al. 1994), activities of daily vision scale (ADVS; Mangione et al. 1992) and visual disability assessment (VDA; Pesudovs & Coster 1998)] are targeted specifically to this population. The majority of visual disability questionnaires have been developed using classical test theory (CTT), wherein the total score reflects the amount of the measured trait (i.e. visual disability). Over the last few years the limitations of the CTT have been widely acknowledged and the use of item response theory (IRT), specifically Rasch analysis, has been advocated (Raczek et al. 1998; Massof 2002; Norquist et al. 2004). Among the numerous properties of Rasch analysis, it also enables insight into content validity and targeting of item difficulty to patient ability, classically not possible with CTT. The aforementioned benefits of IRT provide justification for the testing and re-validation of the pre-existing visual disability instruments using Rasch analysis (Massof 2002). As a step in this direction questionnaires such as the ADVS, VF-14 and VDA have been subjected to revalidation using Rasch analysis (Velozo et al. 2000; Pesudovs et al. 2003; Pesudovs & Noble 2005). However, such an approach is lacking for the visual functioning index (VFI).

The VFI is one of the earliest questionnaires that was developed using CTT to assess visual function in patients with cataract supplement to visual acuity measurement (Bernth-Petersen 1985). The design of the VFI was in part based on the experiences of a pilot questionnaire that was used to assess outcomes of cataract surgery (Bernth-Petersen 1981). Given the limitations of CTT, we applied Rasch analysis to revalidate the VFI in a population of Australian cataract patients awaiting an extraction procedure. The objectives of this study were: (i) to determine whether IRT scoring criteria using Rasch analysis would be appropriate for the VFI; and (ii) to provide clinicians and researchers with an Excel spreadsheet for ready conversion of raw scores to Rasch scores so as to obviate the need for Rasch analysis for assessment of routine clinical outcomes.

Materials and Methods

Participants

The participants of this study were consecutive patients drawn from the cataract surgery waiting list of the Flinders Eye Centre, Flinders Medical Centre, Adelaide, South Australia. Patients were mailed the VFI between January 2006 and October 2008 while on the public waiting list to receive a cataract extraction procedure. Patients self-administered the VFI and returned the completed questionnaire in a prepaid envelope.

The mean age of the patients was 73.9 years [standard deviation (SD) 9.8] and 55% were female. Patients had coexisting ocular (e.g. glaucoma) and systemic (e.g. hypertension) conditions representative of an elderly Australian cataract population and all participants were 18 years or older, English speaking and without severe cognitive impairment. The demographic details of those who completed the VFI are presented in Table 1.

Ethical approval was obtained and all participants signed a consent form. This study was conducted in accordance with the Declaration of Helsinki.

VFI

The VFI was developed in Denmark; the published English version was used in this study (Bernth-Petersen 1985). It consists of 11 items (Table 2) that are grouped into three subgroups: direct visual limitations (three items), mobility limitations caused by visual loss (three items) and social role limitations caused by visual loss (five items). Except for two items that belong to the 'direct visual limitations' subscale, all the other items are rated on a dichotomous scale consisting of either yes/no (seven items – numbers 3, 4, 7, 8, 9, 10 and 11) or sufficient/insufficient (two items – numbers 5 and 6). Two items that belong to the 'direct visual limitations' subscale are scored on a three-point rating scale consisting of 'nothing', 'small printing types' and 'large printing types' for one item (item 1) and 'good', 'moderate' and 'poor' for the other item (item 2). While higher scores represent better visual functioning for three items (numbers 3, 5 and 6), it is vice versa for the remaining items. Having the same order of response options to all the items in a questionnaire can lead to acquiescence, i.e. tendency to agree to items irrespective of their content (Belson 1966; Wiggins 1980; Bradburn 1983). Combining positively and negatively worded items in a single questionnaire

Table 1. Sociodemographics of the study population for the visual functioning index (n = 243).

Characteristic	Result
Mean age, years ± SD	73.9 ± 9.8
Gender, n (%)	
Male	109 (45)
Female	134 (55)
Binocular visual acuity	
Mean ± SD	
LogMAR	0.22 ± 0.20
Snellen	$6/9.5^{-1}$
Range	
LogMAR	−0.26 to 1.00
Snellen	$6/3^{-2‡}$ to 6/60
Awaiting second-eye surgery, n (%)	97 (42)
Ocular comorbidity*, n (%)	
Present	116 (49)
Absent	121 (51)
Duration of cataract (years)	
Median	1
Interquartile range	3
Systemic comorbidity†, n (%)	
Present	200 (93)
Absent	15 (7)

SD, standard deviation.
* Includes glaucoma, diabetic retinopathy, age-related macular degeneration etc. Data were missing for six patients.
† Includes diabetes, hypertension, angina etc. Data were missing for 28 cases.
‡ $6/3^{-2}$ indicates that the patient missed two letters in this line.

Table 2. Items on the visual functioning index.

Item no.	Description	Subscale
1	Reading capacities	Direct visual limitations
2	Distance vision	Direct visual limitations
3	Watching television	Direct visual limitations
4	Vision prevents me from driving or cycling	Mobility limitations
5	Vision sufficient for indoor orientation	Mobility limitations
6	Vision sufficient for outdoor orientation	Mobility limitations
7	Vision limits kind or amount of work or housework	Social role limitations
8	Vision limits kind or amount of other activities	Social role limitations
9	Need help with self-care activities	Social role limitations
10	Need help from community to get along in daily life	Social role limitations
11	Need help from family to get along in daily life	Social role limitations

has been proposed as a solution (Winkler et al. 1982), as has been performed for the VFI. For the purposes of analysis, the response coding can be reversed so that all items are scored in one direction (Locker et al. 2007). We followed this approach and reversed the scoring of these three items so that higher scores represented poorer functioning.

Clinical assessment

Routine clinical assessments were performed prior to cataract extraction. Visual acuity assessments were performed binocularly using computerized testing based on logarithm of the minimum angle of resolution (logMAR) principles. The illumination was 150 cd/m^2. We used binocular acuity for criterion validity testing because it is considered to be representative of real-world ability (Elliott et al. 1990; Rubin et al. 2001).

Statistical analysis

Rasch analysis

The data were analysed using winsteps v3.66 software (Linacre 2008) (Winsteps, Chicago, Illinois, USA). A multiple Andrich rating scale model was applied to the data (Andrich 1978) wherein one model was used for each type (three) and rating scales that behaved in a similar manner were combined. Three fundamental criteria are interpreted in Rasch models: behaviour of the rating scale (or category threshold), fit statistics and separation indices.

Rasch analysis is performed in a sequence. The first step is to determine if the category thresholds are ordered, and if there is disordering then categories are collapsed as disordered thresholds and categories may affect fit. Next, the item fit statistics are examined. These fit statistics are represented by infit (mean square) and outfit (mean square). Fit was evaluated against a range of 0.70–1.30 for infit (weighted) mean squares (Pesudovs et al. 2003). Any misfitting item (fit > 1.30) was removed from the VFI and the Rasch analysis re-run. This iterative process was continued until no further misfit was observed. When deciding removal of a misfitting item every effort should be made to ensure a person separation of > 2.00 even if one has to retain a misfitting item (Mallinson et al. 2004; Garamendi et al. 2006). Winsteps provides reliability for both persons and items in the form of separation reliability and a separation index. The person separation index (PSI) indicates the degree to which study participants can be differentiated into certain groups (PSI range 0–1). Values for PSI of 0.8 are acceptable (Wright & Masters 1982; Prieto et al. 2003). The value of 0.8 is equivalent to a person separation ratio (G) of 2, which means that there are three strata [strata = (4G + 1) / 3] or statistically different levels of person ability that can be distinguished by the items (Wright & Masters 1982; Smith 2001).

The Rasch model provides item locations along a hypothesized common measurement continuum. These calibrations define the hierarchical order of the items along the continuum and the calibrations are expressed in logits (natural log of an odds ratio). In our study logits of greater positive magnitude represent less difficult items and less able persons (i.e. higher visual disability). Winsteps provides a person-item map that places the items and persons along a continuum. Any large gaps along the item difficulty continuum indicate that additional items are needed to distinguish within that particular range of difficulty.

Finally, differences among patients regarding the meaning of each item are assessed using differential item functioning (DIF) (Bond & Fox 2001). DIF allows each item calibration to be compared between two groups in order to assess whether group membership affects responses to VFI items. DIF equal to or larger than 0.5 logits was treated as substantial, demonstrating that response probabilities are not explained fully by the latent trait (i.e. visual disability in this case).

Descriptive data were analysed using statistical analysis software (SPSS v.15; SPSS, Chicago, Illinois, USA) and $p < 0.05$ was considered statistically significant.

Results

A total of 243 patients responded to the VFI. Eleven items were initially fitted to the Rasch model. The overall fit of the data to the model was poor, indicating that the VFI did not form a

Table 3. Summary of the global fit statistics for person ability and item difficulty parameters for the visual functioning index.

Parameter	Separation Index	Separation Reliability	Average infit mean square	Average out fit mean square	Model measurement error	SD
Person ability	1.02	0.51	0.98	0.80	0.98	0.16
Item difficulty	5.30	0.97	0.98	0.99	0.29	0.13

SD, standard deviation.
All values are expressed in logits.

```
  PERSONS - MAP - ITEMS

         <less able>|<less difficult>
 3                  +
                    |  Able to watch TV
                    |
                    |
                    |
                    |  Vision limits self-care activities
                    |
 2                  +
                    |
                    |S
                    |
                    |
                 .  |  Help from community
                    |  Vision sufficient for indoor orientation
 1                  +
                    |
                ## T|
                 .  |
                    |  Vision sufficient for outdoor orientation
                    |
                .#  |
 0               #  +M
                    |  Help from family to get along in daily life
                 .  |
                .#  |
                 .  |  Reading capacities
                 .  |
                 .  |
-1             ### S+  Vision prevents from automobile or bicycle driving
                    |
                 .  |
                .#  |  Vision limits kind or amount of work or housework
                    |
             .####  |S
                 .  |
-2               .  +
                 .  |
                 .  |  Vision limits kind or amount of other activities
             .####  |
                   M|
                    |  Distance vision
                .#  |
-3               .  +
                 .  |
      .###########  |
                    |T
                    |
                    |
                    |
-4                  +
                   S|
                 #  |
                 .  |
       .##########  |
                    |
                    |
-5    .###########  +
         <more able>|<more difficult>

EACH '#' IS 4.
```

Fig. 1. Person-item map for visual functioning index (VFI). The patients are on the left of the dashed line; more able patients are located at the bottom of the map. Items are located on the right of the dashed line; more difficult items are located at the bottom of the map. Each '#' and '.' represent four patients and one patient, respectively. M, mean; S, 1 standard deviation (SD) from the mean; T, 2 SD from the mean.

valid measure. The real-person separation was 1.02 (model person separation 1.24), with a person separation reliability of 0.51 (Table 3). The mean of patients and items was mistargeted with a mean difference of −3.20 logits. Cronbach's alpha was 0.83.

Category thresholds were ordered for all the item groups and none of the items misfit. The person-item map for the VFI is shown in Fig. 1. The mean person ability was −3.20 logits (SD 1.98 logits) (range 1.35 to −6.04), which is significantly different from a normal distribution (Kolmogorov–Smirnov Z-test score = 1.65, p = 0.008) and is higher than the average required by the items. However, the mean person ability for patients with bilateral cataract was statistically significantly lower (−2.85 versus −3.54 logits, independent samples test, F = 0.02, p = 0.01) than for those awaiting surgery in the other eye. The item difficulty ranged from −2.69 to 2.90 logits (Table 4). The person-item threshold map showed a floor effect for persons and an uneven spread of items across the full range of patients' scores. Most of the patients had maximum Rasch scaled scores because of no/little difficulty with the tasks. On the whole the items are less difficult for the abilities of the patients, represented by items being located higher than most of the patients in Fig. 1. While the items are placed sufficiently far apart (> 0.50 logits), indicating that there are no overlapping items, only a third of the items are more difficult than the mean item difficulty (mean = 0). There are few items towards the bottom of the map that would discriminate patients with higher ability.

The most difficult item to endorse was related to the quality of distance vision (item no. 2) and the least difficult item related to watching TV (Table 4).

Table 4. Item fit statistics for the visual functioning index.

Item no.	Item	Item calibration	Standard error	Infit mean square	Outfit mean square
3	Able to watch television	2.90	0.60	1.05	2.72
9	Vision limits self-care activities	2.30	0.48	0.85	0.16
10	Need help from community to get along in daily life	1.35	0.34	0.95	0.52
5	Vision sufficient for indoor orientation	1.15	0.32	1.05	1.27
6	Vision sufficient for outdoor orientation	0.42	0.26	1.00	0.74
11	Need help from family to get along in daily life	−0.07	0.24	0.76	0.45
1	Reading capacities	−0.54	0.17	1.15	1.26
4	Vision prevents me from driving or cycling	−1.07	0.22	1.15	1.16
7	Vision limits kind or amount of work or housework	−1.49	0.19	0.86	0.80
8	Vision limits kind or amount of other activities	−2.26	0.19	0.82	0.72
2	Distance vision	−2.69	0.14	1.10	1.10

All values are expressed in logits.

Only one item showed DIF: patients ≥ 70 years rated reading small/large printing types 0.81 logits relatively easier than other items compared to those aged < 70 years.

We subjected the subscales to Rasch analysis in a similar manner to that of the full version of the VFI. Similar to the full version, the person separation and reliabilities were poor for both the subscales – mobility and social role limitation.

Direct visual limitations

Three items formed this subscale (Table 1). Category thresholds were ordered. The real person separation was 0.28 and reliability was 0.07 (Table 5). One item (Infit MNSQ 1.50) misfit: 'Are you able to watch TV?'. Despite the removal of this item the person separation did not improve, suggesting that this subscale was not a valid measure.

Mobility limitations caused by visual loss

Three items formed this subscale (Table 1). Category thresholds were ordered. The real person separation was 0 and so was the reliability (Table 5). None of the items misfit. There was no DIF. This subscale also did not form a valid measure. Any attempt to improve the functioning of this subscale did not improve its performance.

Social role limitations caused by visual loss

Five items formed this subscale (Table 1). Category thresholds were ordered. The real person separation was 0.59 and reliability was 0.26 (Table 5). None of the items misfit. There was DIF by presence or absence of ocular comorbidity: 'Vision limits the kind or amount of other activities you can do' was rated 1.69 logits easier by the group with no coexisting ocular morbidity.

Discussion

The results indicate that the VFI does not meet the requirements of fit to the Rasch model. The overall questionnaire performed poorly. However, there was no disordering of the category thresholds and thus no need to collapse categories. This finding is in accordance with other studies that have reported shorter rating scales (three or four categories) to function better than the longer scales (Thomee et al. 1995; Pesudovs et al. 2004; Pesudovs & Noble 2005).

The person separation and the reliability of the VFI were well below the accepted level of 2.0 (Bond & Fox 2001). The VFI was able to distinguish among only two strata of patient ability (more able versus less able), reducing the reliability of this instrument to assess cataract surgery outcomes. Low levels of person separation of the VFI in the present study may be attributed partly to the coarse rating scale of the VFI, and partly to the item content.

The lack of misfitting items suggests that all 11 items in the VFI tap the latent trait of visual disability in cataract patients. The person-item map in Fig. 1 shows the relative position of items and persons on an interval scale. This map enables visualization of patient ability and item difficulty on a continuum. Significant mistargeting was evident with a mean difference of 3.20 logits between mean item difficulty and person ability; this was the case irrespective of the level of visual impairment. Good targeting is associated with a smaller distance between mean item difficulty and person ability (Pesudovs et al. 2003). The item difficulty calibrations in the present study ranged from −2.69 to 2.90 logits and spanned 5.59 logits (Table 4 and Fig. 1). The abilities of the patients ranged over 7.39 logits, exceeding the range of the items, with 45 patients obtaining maximum scores (highest ability). There were few items at the bottom half of the map to discriminate patients with greater ability and 141 (60%) patients had no items to discriminate them. Significant gaps

Table 5. Results of testing of subscale fit to the Rasch model for the visual functioning index.

Parameter	Subscale: Direct visual limitations	Mobility limitations	Social role limitations
Person separation	0.28	0	0.59
Person separation reliability	0.07	0	0.26
Mean item location	0	0	0
Mean person location	−3.87	−2.14	−3.80

All values are expressed in logits.

(> 0.50 logits) in the item distribution between –1.49 and –2.26 logits (lower half of Fig. 1), and between 0.42 and 1.15 logits (upper half of Fig.1), were apparent. It appears that the addition of items that represent more difficult activities, including finer-resolution tasks such as reading medicine bottles or food labels etc., would improve targeting of the VFI. The VFI in its present form does not appear suited to a modern cataract surgery population in a developed country and therefore unless more difficult items are added, suboptimal targeting will limit the use of the VFI in cataract outcomes research in this part of the world. This finding concurs with another Rasch revalidated questionnaire for cataract patients, the ADVS (Pesudovs et al. 2003). While the mean person ability for patients with bilateral cataract was significantly lower than for those awaiting surgery in the other eye, the mean person ability of −3.20 logits for the entire sample indicated that the average patient had higher ability (or lower visual disability). This does not suggest that our patients had no visual disability but rather that patients did not experience significant difficulty with tasks included in the VFI; this same population has previously been shown to suffer visual disability according to other measures (Kirkwood et al. 2006). Only one item related to reading capacities represented a task of fine resolution (item 1). Perhaps most of the other items (activities) are too easy for people with visual disability caused by cataract according to current indications. However, because the VFI was developed for patients with much poorer visual acuity, it may still be suitable for countries or regions (South-east Asia with the exception of India, Eastern Mediterranean, China, Africa) with relatively lower cataract surgical rate (i.e. 1–2000/million) (Foster 2000). Thus while using a questionnaire such as the VFI in a different cataract population, factors such as cultural differences (Alonso et al. 1998), the level of development and surgical rate in that country should be considered. It is likely that when the VFI was developed, these items better targeted the ability of the target population, but this seems no longer to be the case. A reduction in the threshold visual impairment or disability for cataract surgery has been widely reported (Leinonen & Laatikainen 2002). If Rasch analysis was used to develop the VFI, it may have led to better targeting of item difficulty to person ability for a sample like ours. Nevertheless, modifications could still make the VFI suit the needs of the cataract patient.

The absence of large DIF (>1.0 logits) in the VFI suggests that the VFI is consistent across subgroups grouped this way. Consistency across subgroups is an important property of a questionnaire if it is to be used in a heterogeneous group of patients (Wang et al. 2006). Furthermore, the absence of large DIF by any gender, age, comorbidity (systemic or ocular) or cataract status demonstrates that the questionnaire would be sufficiently robust to identify large differences in the changes in visual functioning as a result of cataract surgery. Lack of DIF by gender was a surprising finding in our study. Gender-related differences (women experiencing more subjective visual function impairment) have been reported in objective and subjective visual function before and after surgery in a Swedish population (Midelfart 1996; Monestam & Wachtmeister 1998; Lundqvist & Monestam 2008).

Similar to the full version of the VFI, none of the subscales functioned well enough for them to be recommended for routine use. Again, items that specifically target patients with higher ability are needed to improve a subscale's reliability and validity.

Because the results of research are limited if they do not translate to clinical practice, we have developed ready-to-use conversion tables in an Excel spreadsheet that convert the raw scores to Rasch-scaled scores. Thus the inconvenience associated with Rasch-analysing their data is avoided for clinicians.

The present study provides an important first step in the revalidation of the VFI using Rasch analysis. The present study provides evidence that in its current form the 11-item VFI does not fulfil the criteria of the Rasch model. As a result we may question the reliability and validity of this instrument in assessing visual disability in patients with cataract in its current form. One of the simplest methods to increase the reliability of VFI may be to add more items (specifically difficult ones). This addition of items should also improve the poor targeting of the VFI, thereby increasing its suitability for less impaired cataract patients.

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