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Results: The study included 104 patients with cataract, 65 cases with glaucoma and 83 cases with age macular degeneration. Mean age was 70.7 ± 9.9 years, with 143 female (56.7%) and 109 male patients (43.2%). Mean visual acuity was 0.47 and 1.17 logMAR in the better and worse eye, respectively. According to Rasch analysis, three items were found to misfit. Those items belonged to the following subscales: ocular pain and role limitations. The principal component analysis of the residuals showed that 51.9% of the variance was explained by the principal component. Nine items loaded positively onto the first contrast with a correlation higher than 0.4. These items belonged to the following subscales: general health, mental health, role limitations and dependency. After excluding those items, we were able to isolate items from the NEI VFQ-25, related only to a visual functioning component. Finally, the principal component analysis from residuals of this revised version of the NEI VFQ-25 (items related to visual function) showed that the principal component explained 61.2% of the variance, showing no evidence of multidimensionality.

Conclusions: The Portuguese version of the NEI VFQ-25 is not an unidimensional instrument. We were able to find items that belong to a different trait, possible related to a socio-emotional component. Thus, in order to obtain psychometrically valid constructs, both visual functioning and socio-emotional components should be analyzed separately.
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Psychometric Properties of the Portuguese Version of the National Eye Institute Visual Function Questionnaire-25

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Abstract

Background: To investigate the psychometric properties of the Brazilian Portuguese version of the National Eye Institute Visual Function Questionnaire (NEI VFQ-25) in a group of patients with different eye diseases.

Methods: Cross-sectional study. All subjects completed the Portuguese version of the NEI VFQ-25 questionnaire. Another questionnaire containing a survey about clinical and demographics data was also applied. Rasch analysis was used to evaluate the psychometric properties of the NEI VFQ-25.

Results: The study included 104 patients with cataract, 65 cases with glaucoma and 83 cases with age macular degeneration. Mean age was 70.7 ± 9.9 years, with 143 female (56.7%) and 109 male patients (43.2%). Mean visual acuity was 0.47 and 1.17 logMAR in the better and worse eye, respectively. According to Rasch analysis, three items were found to misfit. Those items belonged to the following subscales: ocular pain and role limitations. The principal component analysis of the residuals showed that 51.9% of the variance was explained by the principal component. Nine items loaded positively onto the first contrast with a correlation higher than 0.4. These items belonged to the following subscales: general health, mental health, role limitations and dependency. After excluding those items, we were able to isolate items from the NEI VFQ-25, related only to a visual functioning component. Finally, the principal component analysis from residuals of this revised version of the NEI VFQ-25 (items related to visual function) showed that the
principal component explained 61.2% of the variance, showing no evidence of multidimensionality.

**Conclusions:** The Portuguese version of the NEI VFQ-25 is not an unidimensional instrument. We were able to find items that belong to a different trait, possible related to a socio-emotional component. Thus, in order to obtain psychometrically valid constructs, both visual functioning and socio-emotional components should be analyzed separately.

**Keywords:** Glaucoma; Quality of life; National Eye Institute Visual Function Questionnaire; NEI VFQ-25; Rasch Analysis; Cataract; AMD
Introduction

Quality of life (QoL) is a broad-ranging concept affected by an individual’s physical health, psychological state, level of independence and social relationships.[1, 2] Within physical health, sense of sight is crucial to perform many routine daily activities. Therefore, changes in visual status can lead to functional impairment affecting directly QoL. Conventional clinical measures such as visual acuity, visual field assessment and fundus imaging may not fully capture the impact of disability related to eye diseases. Thus measurements of health-related QoL have been used to track outcomes for many eye diseases.[3, 4] Even though many so-called health-related QoL questionnaires can measure only a self-perceived health status, the importance of evaluating the outcomes of health care from the standpoint of the patient is now widely recognized.[5, 6]

Within patient-reported questionnaires, the National Eye Institute Visual Function Questionnaire (NEI VFQ-25) has been frequently used to assess QoL in ophthalmology research.[7-10] This questionnaire contains a set of 25 questions in 12 subscales designed to assess the dimensions of self-reported vision-target health status that are relevant for subjects with chronic eye diseases.[7] Items in the questionnaire require the subject to provide a response based on a Likert scale and methods for analyzing this type of data used in most previous studies attribute linear scores to each response and then sum up the scores for all different questions to obtain a single composite score. However, in order for a composite score to be meaningful is essential that all questions included in the scoring contribute to the measurement of a single underlying construct.[3, 11] For example, for the NEI VFQ-25 responses to be represented by a single score, its questions should all be
measuring the same latent construct of visual functioning.

Rasch analysis is a method that can be used to investigate psychometric properties of questionnaires, such as dimensionality and reliability. Massof et al administered some items from the 52-NEI-VFQ to patients with low vision, applying Rasch model to estimate interval measurement scales from ordinal responses to items.[11] They found that Rasch analysis can offer an alternative to traditional scoring methods enabling one to estimate the latent variable of interest (visual function) and assess the performance of each item as a contributor to the final measurement. In a subsequent work, Marella and colleagues have suggested that the NEI VFQ-25 questionnaire does not seem to be unidimensional, and that the questionnaire items may actually be measuring two different underlying constructs, one related to visual functioning and another to socio-emotional status. This is important, as it would indicate that a single composite score is not appropriate to represent responses to this questionnaire. [12, 13] In addition to dimensionality, Rasch analysis can provide information about appropriateness of the response categories, measurement precision, and item fit to the construct.[14, 15] Rasch analysis of the English version of the NEI VFQ-25 has also suggested that the subscales represented on the questionnaire would not be valid in their current format.[16]

As a widely used instrument to assess vision-related QoL, the NEI VFQ-25 has been translated into several different languages. When a questionnaire is translated into a new language, a linguistic validation is necessary but not sufficient unless the psychometric characteristics have been verified. Simao et al. introduced the Brazilian Portuguese version of the NEI VFQ-25 in 2008 and reported psychometrics properties comparable to the American original version.[17] However, the work of Simao et al
reported only measures such as Cronbach’s alpha and correlations among subscales. The reason Rasch analysis is well suited for demonstrating a translated version of an existing questionnaire has comparable items to the original is its sensitivity to differences in item difficulty. [18] Cronbach’s alpha, for example, is insensitive to this, and can provide the same value for two questionnaires whose items differ in levels of difficulty. Thus, a proper validation of the Portuguese translation of the questionnaire would also benefit from a method such as Rasch analysis to better assess dimensionality and validity. To the best of our knowledge no study has yet applied the Rasch Analysis to the Portuguese version of the NEI VFQ-25 questionnaire. Thus, the purpose of current study is to investigate the psychometric properties of NEI VFQ-25 using Rasch analysis in a population of Brazilian patients with a variety of eye diseases.

**Materials and Methods**

This was a cross sectional study, evaluating patients with glaucoma, cataract and age-related macular degeneration (AMD) from the Hospital das Clínicas – University of Campinas – Brazil. This study was approved by the Ethics Committee of the University of Campinas and adhered to the tenets of the Declaration of Helsinki. Subjects underwent a comprehensive ophthalmic examination, including Snellen best corrected visual acuity, slit-lamp biomicroscopy, intraocular pressure (IOP) measurement using Goldmann applanation tonometry, gonioscopy and dilated fundoscopy examination using a 78-diopter lens. Subjects underwent standard automated perimetry, using the 24-2 Swedish
Interactive Threshold Algorithm (SITA) Standard (Humphrey, Carl Zeiss Meditec, Inc., Dublin, CA, USA) and also retinal imaging with nonmyd WX³D (Kowa, Japan).

Three different groups were investigated. Glaucoma patients were required to have repeatable (at least 2 consecutive) abnormal SAP results with corresponding glaucomatous optic nerve damage in at least one eye. An abnormal SAP result was defined as a pattern standard deviation with P < 0.05, and/or Glaucoma Hemifield Test results outside normal limits. Cataracts were classified according to the Lens Opacities Classification System III (LOCS III) based on findings from slit lamp examination.[19]

For AMD, we applied the Clinical Age-Related Maculopathy Staging system, which divides patients into 5 mutually exclusive categories based on slit-lamp assessment of drusen, retinal pigment epithelial irregularities, geographic atrophy, retinal pigment epithelial detachment, and choroidal neovascularization.[20, 21]

**NEI VFQ-25 Questionnaire**

The NEI VFQ was originally developed with 51 items to capture the influence of vision impairment on multiple dimensions of health related QoL, such as emotional status and social functioning. Mangione et al validated a shorter and reliable version with 25 items.[7] We assessed vision-related QoL using a Brazilian Portuguese version of the NEI VFQ-25 questionnaire.[7] This version was developed by Simao et al in 2008 and was initially tested for in a set of ophthalmic patients and healthy controls.[17] The NEI VFQ-25 consists of 25 questions measuring overall vision, difficulty with near-vision and distance activities, ocular pain, driving difficulties, limitations with peripheral vision and
color vision, social functioning, role limitations, dependency and mental health symptoms. The questionnaire was interview-administered.

Rasch analysis

Rasch analysis was performed to obtain final estimates of “person measures,” which can be used to express where each respondent falls on a linear scale representing the degree of impairment as measured by the NEI VFQ-25.[22, 23] Rasch analysis was performed using Andrich rating-scale models to obtain the estimates of the required ability of each item, perceived ability of each subject, and the thresholds for each response category.[14] The unit of those estimated measures is called a logit (log-odds unit), which is calculated as the log-odds ratio of the probability that a participant will select a particular rating category in an item over 1 minus the same probability. The logit values place patients according to their abilities and items according to their difficulties on the same linear interval scale. [24]

Person and item measures were examined for fit to the Rasch model using infit and outfit item fit statistics.[8] To test the hypothesis that the NEI VFQ-25 measures a single underlying construct, we initially evaluated the fit statistics, which were recorded as mean square standardized residuals (MNSQ); The fit of the Rasch model was evaluated with the infit and outfit statistics. Values between 0.7 and 1.3 are considered acceptable for MNSQ values of infit and outfit.[25] After checking fit statistics, we conducted a principal components analysis of the residuals (difference between the
observed and expected responses).[26] Data are considered unidimensional if most of the variance is explained by the principal component and there is no significant explanation of the residual variance by the contrasts to the principal component. In general, to be considered unidimensional, the variance of the principal component should be >60%.[8, 26] Furthermore, the unexplained variance by the contrasts should be <2 Eingenvalue units.[26]

We also evaluated differential item functioning, which assesses whether the items have different meanings for different groups in the sample. The raw differences in item calibration between groups were examined to identify differential item functioning. The differential item functioning was considered absent if it was less than 0.50 logits, minimal but probably inconsequential if it ranged between 0.50 and 1.0 logits, and notable if it was >1.0 logit.[12, 27]

The person separation index is the ratio of the variance in the person measures for the sample to the average error in estimating these measures. It is a measure of how broadly the persons could be distinguished into statistically distinct levels. The person separation reliability coefficient describes the reliability of the scale to discriminate between the persons of different abilities.[12] A person separation index of ≥ 2.0 or a reliability value of ≥ 0.8 represents the minimum acceptable level of separation.[12, 25]

Demographic, Clinical and Socio-economic Variables

Socio-economic questionnaires were also administered along with the NEI VFQ-25 to all patients. These questionnaires contained a survey about demographics, history of ocular and medical conditions, marital status, degree of education and income. For
comorbidities, we investigated the presence or history of the following conditions:
diabetes mellitus, arthritis, high blood pressure, heart disease, depression, asthma, and
cancers. A simple summation score was used to create a comorbidity index.[28] As these
variables could potentially affect patient perceptions about vision-related QOL, they were
included as covariates factors to investigate their association with the final Rasch-
calibrated NEI VFQ-25 scores. These variables were categorized for inclusion in the
univariate and multivariate models as race (African American [yes/no]), employment
(yes/no), marital status (married [yes/no]), degree of education (at least high school
degree [yes/no]) and income (less than $25,000/year [yes/no]). Visual acuity was
measured using an Early Treatment Diabetic Retinopathy (ETDRS) chart and logMAR
measurements were used in the analyses evaluating better and worse eye.[29] For patients
with visual acuity measures of “counting fingers” (CF), “hand motion”, “light
perception” and “no light perception” (NLP), we converted into quantitative
measurements such as logMAR, as suggested by Schulze-Bonsel. [29]

**Statistical Analysis**

Descriptive statistics included mean and standard deviation for normally
distributed variables. We investigated the relationship between final Rasch-calibrated
NEI VFQ-25 scores with socioeconomic and clinical variables (gender, race, education,
income, marital status, visual acuity in logMAR, presence of low vision and mean
deviation from standard automated perimetry) using a linear regression model. Variables
with P value < 0.2 were included in the final multivariable linear regression model.
Statistical analyses were performed using Winsteps 3.81.0 (Chicago, IL) and STATA v.
Results

The study included 104 patients with cataract, 65 cases with glaucoma and 83 cases with AMD. Table 1 presents demographic variables of the studied population. Mean age was 70.7 ± 9.9 years, with 143 female (56.7%) and 109 male patients (43.2%). Most of them were retired (74%). Table 2 describes the clinical variables of the patients. Mean visual acuity in the better eye was 0.47 logMAR and 1.17 logMAR in worse eye. There were 62 patients (24.6%) with low vision (counting fingers, hand motion, light perception or loss of light perception in one or both eyes).
Table 1. Demographic characteristics of all patients included in the study.

| Parameters                        | Total subjects (n = 252) |
|-----------------------------------|--------------------------|
| **Age (years)**                   |                          |
| Mean ± SD                         | 70.7± 9.9                |
| Range                             | 30 to 103                |
| **Gender, n (%)**                 |                          |
| Male                              | 109 (43.2%)              |
| Female                            | 143 (56.7%)              |
| **Race, n (%)**                   |                          |
| Caucasian                         | 204 (81.2%)              |
| African-American                  | 44 (17.5%)               |
| **Job status (%)**                |                          |
| Employed                          | 44 (18.1%)               |
| Unemployed                        | 19 (7.8%)                |
| Retired                           | 180 (74.0%)              |
| **Marital status (%)**            |                          |
| Married                           | 119 (69.5%)              |
| Single                            | 25 (14.6%)               |
| Widowed                           | 14 (8.1%)                |
| Divorced                          | 13 (7.6%)                |
| **Education (%)**                 |                          |
| Illiterate                        | 2 (0.8%)                 |
| Elementary school                 | 137 (56.6%)              |
| High school degree                | 58 (23.9%)               |
| College degree                    | 8 (3.2%)                 |
| **Income per month (%)**          |                          |
| Lower than US$414.00              | 81 (48.2%)               |
| Between US$414.00 and US$2,073.00| 68 (40.4%)               |
| Between US$2,073.00 and US$4,147.00| 17 (10.1%)             |
| Higher than US$4,147.00           | 2 (1.1%)                 |
| **Comorbidity Index (%)**         |                          |
| Zero                              | 71 (28.9%)               |
| One                               | 109 (44.4%)              |
| Two                               | 58 (23.6%)               |
| Three                             | 6 (2.4%)                 |
Table 2. Clinical characteristics of all patients included in the study.

| Parameters                                                                 | Total subjects (n = 252) |
|----------------------------------------------------------------------------|--------------------------|
| LogMar Visual acuity (better eye)                                          |                          |
| Mean ± SD                                                                  | 0.47 ± 0.39              |
| LogMar Visual acuity (worse eye)                                          |                          |
| Mean ± SD                                                                  | 1.17 ± 0.74              |
| SAP MD from glaucoma (better eye) (dB)                                     |                          |
| Mean ± SD                                                                  | -4.26 ± 3.85             |
| SAP MD OS from glaucoma (worse eye) (dB)                                   |                          |
| Mean ± SD                                                                  | -10.77 ± 9.38            |
| Low vision, n (%)                                                          | 62 (24.6%)               |

SD: standard deviation; SAP: standard automated perimetry; MD: mean deviation; OD: right eye; OS: left eye.

Rasch Analysis

Results of Rasch analysis are shown in Table 3. Three items (Q4, Q17, and Q19) were found to misfit (from subscales: ocular pain and role limitations) with infit mean scores >1.3. Figure 1 shows a scatterplot with the items with misfit. Principal components analyses of the residuals from Rasch analysis can also be used to check the assumption of unidimensionality.[30] In order to determine whether the assumption of unidimensionality is valid, the variance explained by the Rasch factor (the underlying construct) should be 4 times greater than that of the first principal component in the residuals and the variance explained by the Rasch factor should be greater than 60%.[31]
Fig 1. Scatterplot of infit versus outfit statistics for item measures estimated from responses to items in the National Eye Institute Visual Function Questionnaire (NEI VFQ-25). The box bounds the 1.3 unacceptable limits, highlighting the misfitting items inside the box.

Table 3. Fit Statistics using Rasch Analysis with respective Items and Subscales from National Eye Institute Visual Function Questionnaire (NEI VFQ-25).

| Questions                        | Items                      | Subscales      | Measure | Infit MNSQ | Outfit MNSQ |
|----------------------------------|----------------------------|----------------|---------|------------|-------------|
| Q1 General health                | General health             | General health | -0.19   | 1.09       | 1.12        |
| Q2 General vision                | General vision             | General vision | -0.30   | 0.62       | 0.77        |
| Q3 Worry about eyesight          | Mental health              | Mental health  | -0.46   | 1.05       | 1.21        |
| Q4 Pain around eyes              | Ocular pain                | Ocular pain    | 0.41    | 1.58       | 2.03        |
| Q5 Reading normal newsprint      | Near vision                | Near vision    | -0.22   | 0.93       | 0.93        |
| Q6 Seeing well up close          | Near vision                | Near vision    | 0.07    | 0.89       | 0.84        |
| Q7 Finding objects on crowded shelf | Near vision             | Near vision    | 0.40    | 0.79       | 0.73        |
| Q8 Street signs                  | Distance vision            | Distance vision| 0.13   | 0.91       | 0.92        |
| Q9 Going downstairs at night     | Distance vision            | Distance vision| 0.30   | 0.79       | 0.75        |
| Q10 Seeing objects off to side   | Peripheral vision          | Peripheral vision| 0.36  | 0.72       | 0.68        |
| Q11 Seeing how people react      | Social function            | Social function| 0.91   | 0.90       | 0.61        |
| Q12 Matching clothes             | Color vision               | Color vision   | 0.79    | 0.85       | 0.84        |
| Q13 Visiting others              | Social function            | Social function| 0.56   | 1.05       | 0.88        |
| Q14 Going out to movies/plays    | Distance vision            | Distance vision| 0.26   | 1.19       | 1.24        |
| Q17 Accomplish less              | Role limitations           | Role limitations| -0.37 | 1.40       | 1.41        |
| Q18 Limited endurance            | Role limitations           | Role limitations| -0.42 | 0.88       | 0.83        |
| Q19 Amount of time in pain       | Ocular pain                | Ocular pain    | -0.18   | 1.65       | 1.75        |
| Q20 Stay home most of the time   | Dependency                 | Dependency     | -0.32   | 0.89       | 0.83        |
| Q21 Frustrated                   | Mental health              | Mental health  | -0.51   | 1.06       | 1.02        |
| Q22 No control                   | Mental health              | Mental health  | -0.32   | 1.01       | 0.92        |
| Q23 Rely too much on others' words | Dependency               | Dependency     | -0.51   | 1.07       | 0.87        |
| Q24 Need much help from others   | Dependency                 | Dependency     | -0.40   | 0.96       | 0.87        |
| Q25 Embarrassment                | Mental health              | Mental health  | -0.51   | 1.30       | 0.99        |

MNSQ: mean square
For the current work, the principal component analysis of the residuals showed that the variance explained by the principal component was comparable for empirical calculation (50.9%) and by the model (51.9%). This suggests that the questionnaire was not unidimensional. Moreover, the unexplained variance explained by the first contrast was 3.38 eigenvalue units and the second contrast was 2.56 eigenvalue units with no further contrasts exceeding 2.0 eigenvalue units. These findings suggested the presence of a second dimension in the scale. We analyzed the principal components/contrast plots of items loadings and found items belonging to different clusters with high positive loadings (correlation>0.4) onto the first contrast. We also identified 3 different clusters and exclude items from General health (Q1), Mental Health (Q3, Q21, Q22 and Q25), Role limitations (Q18), Dependency (Q20, Q23 and Q24), that belonged to a secondary dimension underlying the first contrast, which could be biasing the person measures. This suggests that these nine items cannot be grouped with other items in the scale to measure a single latent trait (visual functioning). These items are probably related to a social-emotional component. Of note, in the current sample, 187 patients (74.4%) answered that they were not currently driving (Q15). Within this group, 158 patients (84.5%) reported that they never had driven (Q15a). Therefore questions related to driving were not assessed in the Rasch Analysis due to missing data.

Differential item functioning was tested for some of the variables from Table 1 and Table 2, such as: age, gender, race, job status, marital status, education, level of income, low vision and type of eye disease (cataract, glaucoma and AMD). There was no differential item functioning for any of the variables mentioned. These results suggest that items could be interpreted similarly across subgroups of the sample. After excluding
items that were considered misfitted (Q4, Q17 and Q19) and also those items with high loadings on the principal component analysis of the residuals, such as: General health (Q1), Mental Health (Q3, Q21, Q22 and Q25), Role limitations (Q18), Dependency (Q20, Q23 and Q24), we were able to isolate items from the NEI VFQ-25, related only to the visual function component. According to Table 4, no items were misfitted. We also performed a principal component analysis of the residuals of the revised version of the NEI VFQ-25 (items related to visual function). The final variance of the principal component was 61.2% and the unexplained variance by the contrasts is 1.64 eingenvalue units, showing no evidence of multidimensionality (Table 5). The mean (± SD) of the person measures was -3.02 ± 1.09 logits. We investigate targeting using Wright person-item maps (Figure 2). We found that our sample did not ideally matched items for both original versions of NEI VFQ-25. Even after removal of misfitting items, most of the items (right-side, top of the scale) were not able to cover people with most visual ability (left side, bottom of the scale). The separation index for person measures was 2.44, with reliability of 0.86. We also reported the psychometric properties of the socioemotional component of the NEI VFQ-25 (Table 5).

**Fig. 2.** Wright item-person maps related to visual function of the revised version of the National Eye Institute Visual Function Questionnaire (NEI VFQ-25). The left-hand column locates the person ability measures along the variable. The right-hand column locates the item difficulty measures along the variable.
Table 4. Fit Statistics from Rasch Analysis with respective Items and Subscales using the only item related to visual function of the National Eye Institute Visual Function Questionnaire (NEI VFQ-25).

| Questions         | Items                                | Subscales     | Measure | Infit MNSQ | Outfit MNSQ |
|-------------------|--------------------------------------|----------------|---------|------------|-------------|
| Q2                | General vision                       | General vision| -1.13   | 0.77       | 0.92        |
| Q5                | Reading normal newsprint              | Near vision   | -1.06   | 1.10       | 1.08        |
| Q6                | Seeing well up close                 | Near vision   | -0.47   | 0.99       | 0.99        |
| Q7                | Finding objects on crowded shelf     | Near vision   | 0.23    | 0.90       | 0.84        |
| Q8                | Street signs                         | Distance vision| -0.34 | 0.98       | 0.96        |
| Q9                | Going downstairs at night            | Distance vision| 0.02   | 0.90       | 1.00        |
| Q10               | Seeing objects off to side           | Peripheral vision| 0.14 | 0.75       | 0.71        |
| Q11               | Seeing how people react              | Social function| 1.17   | 1.00       | 0.88        |
| Q12               | Matching clothes                     | Color vision  | 0.97    | 0.88       | 1.04        |
| Q13               | Visiting others                      | Social function| 0.54   | 1.25       | 1.15        |
| Q14               | Going out to movies/plays            | Distance vision| -0.07  | 1.21       | 1.22        |

MNSQ: mean square
Table 5. Rasch Analysis Fit Statistics of the Visual Function and Socioemotional Components from the National Eye Institute Visual Function Questionnaire (NEI VFQ 25).

| Components                  | Visual Function | Socioemotional |
|-----------------------------|-----------------|----------------|
| Items in Scale (n)          | 11              | 8              |
| Misfitting Items (n)        | None            | 2 (Q1 and Q3)  |
| Person Separation Index     | 2.44            | 1.34           |
| Person Separation Reliability (logits) | 0.85           | 0.64           |
| Mean Person Measure (logits)| -3.02           | -1.12          |
| Final variance of Principal Component (%) | 61.20          | 64.1           |

We also investigated the association between demographic and clinical variables with the final scores of the revised version of the NEI VFQ-25. Within the clinical and demographic variables, there was a statistical relationship with the Rasch-calibrated scores in NEI VFQ-25 for the following variables in univariable models: visual acuity in the better eye (P<0.001), visual acuity in the worse eye (P<0.001), patients with low vision (P<0.001), gender (P<0.001), marital status (P=0.001), employment status (P=0.019), education level (P<0.001) and comorbidity index (P=0.003). In a multivariable analysis, only 2 variables remained statistically significant: visual acuity in the better eye (P<0.001) and education level (P=0.002).
Discussion

In the current study, we investigated the psychometric properties of the Brazilian Portuguese version of the NEI VFQ-25 using Rasch analysis. Our results showed that the NEI VFQ-25 does not seem to be an unidimensional instrument; that is, it does not measure a single latent construct (quality of life related to visual function).[11] Although most items on the NEI VFQ-25 tap the construct of visual functioning, our results indicated that other items belonged to a different construct, namely socio-emotional component, corroborating findings from previous studies.[12, 13]

Unidimensionality of an instrument can be assessed by examining the fit statistics and principal component analysis of the residuals. Ideally items should have MNSQ values between 0.7 and 1.3. Items with MNSQ lower than 0.7 suggest a high level of predictability in the responses, indicating redundancy, [25] whereas values higher than 1.3 show an unacceptable level of noise in the responses. According to Table 3, four items (Q4, Q19, Q24 and Q25) were found to misfit. Those items belonged to the subscales of mental health, ocular pain and role limitations. In Figure 1 we can observe a scatterplot with the items that we considered misfitted. When the variance of the principal component is considered high (60% or greater), there is a low likelihood of additional components [13]. In the current study, the principal component analysis of the residuals showed that the variance explained by the principal component was 51.9%. In addition to that, if the variance explained by the principal component for the real data and the model are similar, the chances of finding additional constructs are low. When patterns within variance are unexplained by the principal component, a second construct can be
measured. This finding is reported by the first contrast in the residuals. According to previous study, a contrast should have an eigenvalue higher than 2.0 to be considered as an evidence of a second construct being greater than the magnitude seen with random data [13]. Our initial analysis showed a first contrast with 3.38 eigenvalue units, suggesting that the Brazilian Portuguese version of the NEI VFQ-25 was not unidimensional. The loading of items onto the contrasts allows identification of which items tap different constructs. In our analysis, nine items loaded positively onto the first contrast with a correlation higher than 0.4. These items belonged to the following subscales: General health (Q1), Mental Health (Q3, Q21, Q22 and Q25), Role limitations (Q18), Dependency (Q20, Q23 and Q24). This suggests that these nine items cannot be grouped with other items in the scale to measure a single latent construct, such as QoL related to visual function. The purpose of using principal component analysis and inspecting contrast plots is to find patterns in the dataset and discover groups of items that share the same patterns of unexpectedness, which could represent a secondary dimension, proving that the instrument is not unidimensional.

We were able to isolate items from the NEI VFQ-25, related only to a visual function component, after excluding items that were considered misfitted and also those items with high loadings on the principal component analysis of the residuals. When we re-examined the fit statistics of this revised version of the NEI VFQ-25, no items were misfitted (Table 4). Moreover, the final variance of the principal component was 61.2% and the unexplained variance by the first contrast was 1.64 eigenvalue units (Table 5). These results suggest that this revised version of the NEI VFQ-25 showed no evidence of
multidimensionality. The Wright person-item map revealed that items did not adequately covered all spectrums of visual abilities. In fact, most of uncovered percentage of patients represents persons with more visual ability (Figure 2). This may be explained by our sample did not include enough people with significant visual impairment. Simao et al used a “Factor analysis” and concluded that almost all subscales of NEI VFQ-25 belong to the same underlying dimension. However, careful analysis of their data suggests some evidence of multidimensionality.[17] For example, they showed that most of the subscales from the Portuguese version of the NEI VFQ-25 were influenced by central vision correlated with the first factor, while the “General vision”, “Ocular pain” and “Peripheral vision” subscales were included in a second factor.[17] We were able to find a second construct more related to a socio-emotional component formed by subscales such as: “General health”, “mental health”, “role limitations” and “dependency”, in contrast to central and peripheral vision constructs as highlighted in the previous study. This difference might be due to application of different types of analysis (Rasch as opposed to Factor Analysis). Factor Analysis assumes that distances on the scales are equal and the sum the responses of each item not taking into account item hierarchy. Rasch analysis can build a measure with items assuming a hierarchy level..[32] In fact, Pesudovs et al investigated the psychometric properties of the NEI VFQ-25 with Rasch analysis in a group of patients with cataract and found that several subscales were not psychometrically sound. They concluded that the NEI VFQ-25 as an overall measure was flawed by multidimensionality.[13] In addition, Marella et al performed a similar investigation with a group of low vision patients and also found that the NEI VFQ-25 is a better performing instrument when divided into two different scales, with items from
General health (Q1), Mental Health (Q3, Q21, Q22 and Q25), Role limitations (Q18), Dependency (Q20, Q23 and Q24) belonging to a secondary dimension, corroborating the findings of our study. [12]

Another important characteristic of a good instrument is that items function similarly for persons at the same level of ability. Differential item functioning was tested for the following variables: age, sex, race, job status, marital status, education, level of income, low vision and type of eye disease (cataract, glaucoma and AMD). Differential item functioning occurs when subgroups of people with comparable levels of ability respond differently to an item, which implies a response to some characteristic other than item difficulty. We were not able to find evidence of differential item functioning for any of the variables mentioned. Thus, our results suggest that items from the Portuguese version of the NEI VFQ-25 could be interpreted similarly across subgroups of the sample, including different eye diseases, such as cataract, glaucoma and AMD.

We found that worse visual acuity and patients with lower education level had lower Rasch-calibrated NEI VFQ-25 scores. Even though patients with AMD had lower Rasch-calibrated scores of NEI VFQ-25 compared to cataract and glaucoma patients, when adjusting for visual acuity, the correlation with different types of eye disease in the multivariable analysis was not statistically significant, implying that visual acuity may be a better predictor for vision related QoL in comparison to the underlying cause of the vision loss. In fact, associations between worse visual acuity and QoL have already been demonstrated.[7, 33] Moreover, previous work have suggested that poor educated patients might have higher levels of emotional distress (including depression, anxiety,
and anger) and physical distress (including aches and pains and malaise), which could influence the responses of the QoL questionnaire.[34]

The current study has limitations. Even though Rasch analysis is becoming the gold standard for scoring patient-reported outcome measures in ophthalmology, a multilevel model that allows simultaneous analysis of different dimensions in a multidimensional instrument could also be used.[8, 10, 35] Our sample consisted of patients with cataract, glaucoma and AMD. Thus, future studies should investigate psychometric validity of the Rasch calibrated version of the NEI VFQ-25 in a sample with more varied range of eye diseases.

**Conclusion**

Our findings indicate that the Brazilian Portuguese version of the NEI VFQ-25 is not psychometrically optimal for assessing QoL related only to visual function. Rather, we found a second trait, described as a socioemotional component from results of the Rasch analysis. Thus, in order to obtain psychometrically valid constructs, both components with their respective subscales and items (visual functioning and socioemotional) should be analyzed separately. Future studies in Brazil including patients with different eye diseases are needed to substantiate our findings and evaluate the sensitivity of this calibrated version of the NEI VFQ-25.
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Psychometric Properties of the Portuguese Version of the National Eye Institute
Visual Function Questionnaire-25

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Abstract

Background: To investigate the psychometric properties of the Brazilian Portuguese version of the National Eye Institute Visual Function Questionnaire (NEI VFQ-25) questionnaire in a group of patients with different eye diseases.

Methods: Cross-sectional study. All subjects completed the Portuguese version of the NEI VFQ-25 questionnaire. Another questionnaire containing a survey about clinical and demographics data was also applied. Rasch analysis was used to evaluate the psychometric properties of the NEI VFQ-25.

Results: The study included 104 patients with cataract, 65 cases with glaucoma and 83 cases with age macular degeneration. Mean age was 70.7 ± 9.9 years, with 143 female (56.7%) and 109 male patients (43.2%). Mean visual acuity was 0.47 and 1.17 logMAR in the better and worse eye, respectively. According to Rasch analysis, four-three items were found to misfit. Those items belonged to the following subscales: mental health, ocular pain, ocular pain and role limitations. The principal component analysis of the residuals showed that 51.9% of the variance was explained by the principal component. Eight-Nine items loaded positively onto the first contrast with a correlation higher than 0.4. These items belonged to the following subscales: general health, mental health, role limitations and dependency. After excluding those items, we were able to isolate items from the NEI VFQ-25, related only to a visual functioning component. Finally, the principal component analysis from residuals of this revised version of the
NEI VFQ-25 (items related to visual function) showed that the principal component explained 61.2% of the variance, showing no evidence of multidimensionality.

Conclusions: The Portuguese version of the NEI VFQ-25 is not a unidimensional instrument. We were able to find items that belong to a different trait, possible related to a socio-emotional component. Thus, in order to obtain psychometrically valid constructs, both the visual functioning and socio-emotional components should be analyzed separately.

Keywords: Glaucoma; Quality of life; National Eye Institute Visual Function Questionnaire; NEI VFQ-25; Rasch Analysis; Cataract; AMD
**Introduction**

Quality of life (QoL) is a broad-ranging concept affected by an individual’s physical health, psychological state, level of independence and social relationships.[1, 2] Within physical health, sense of sight is crucial to perform many routine daily activities. Therefore, changes in visual status can lead to functional impairment affecting directly QoL. Conventional clinical measures such as visual acuity, visual field assessment and fundus imaging may not fully capture the impact of disability related to eye diseases. Thus measurements of health-related QoL have been used to track outcomes for many eye diseases.[3, 4] Even though many so-called health-related QoL questionnaires can measure only a self-perceived health status, the importance of evaluating the outcomes of health care from the standpoint of the patient is now widely recognized.[5, 6]

Within patient-reported questionnaires, the National Eye Institute Visual Function Questionnaire (NEI VFQ-25) has been frequently used to assess QoL in ophthalmology research.[7-10] This questionnaire contains a set of 25 questions in 12 subscales designed to assess the dimensions of self-reported vision-target health status that are relevant for subjects with chronic eye diseases.[7] Items in the questionnaire require the subject to provide a response based on a Likert scale and methods for analyzing this type of data used in most previous studies attribute linear scores to each response and then sum up the scores for all different questions to obtain a single composite score. However, in order for a composite score to be meaningful is essential that all questions included in the scoring contribute to the measurement of a single underlying construct.[3, 11] For example, for...
the NEI VFQ-25 responses to be represented by a single score, its questions should all be measuring the same latent construct of visual functioning.

Rasch analysis is a method that can be used to investigate psychometric properties of questionnaires, such as dimensionality and reliability. Massof et al administered some items from the 52-NEI-VFQ to patients with low vision, applying Rasch model to estimate interval measurement scales from ordinal responses to items. They found that Rasch analysis can offer an alternative to traditional scoring methods enabling one to estimate the latent variable of interest (visual function) and assess the performance of each item as a contributor to the final measurement. In a subsequent work, Marella and colleagues have suggested that the NEI VFQ-25 questionnaire does not seem to be unidimensional, and that the questionnaire items may actually be measuring two different underlying constructs, one related to visual functioning and another to socio-emotional status. This is important, as it would indicate that a single composite score is not appropriate to represent responses to this questionnaire. In addition to dimensionality, Rasch analysis can provide information about appropriateness of the response categories, measurement precision, and item fit to the construct. Rasch analysis of the English version of the NEI VFQ-25 has also suggested that the subscales represented on the questionnaire would not be valid in their current format.

As a widely used instrument to assess vision-related QoL, the NEI VFQ-25 has been translated into several different languages. When a questionnaire is translated into a new language, a linguistic validation is necessary but not sufficient unless the psychometric characteristics have been verified. Simao et al. introduced the Brazilian Portuguese version of the NEI VFQ-25 in 2008 and reported psychometrics properties...
comparable to the American original version.[17] However, the work of Simao et al reported only measures such as Cronbach’s alpha and correlations among subscales. The reason Rasch analysis is well suited for demonstrating a translated version of an existing questionnaire has comparable items to the original is its sensitivity to differences in item difficulty.[18] Cronbach’s alpha, for example, is insensitive to this, and can provide the same value for two questionnaires whose items differ in levels of difficulty. Thus, a proper validation of the Portuguese translation of the questionnaire would also benefit from a method such as Rasch analysis to better assess dimensionality and validity. To the best of our knowledge no study has yet applied the Rasch Analysis to the Portuguese version of the NEI VFQ-25 questionnaire. Thus, the purpose of current study is to investigate the psychometric properties of NEI VFQ-25 using Rasch analysis in a population of Brazilian patients with a variety of eye diseases.

Materials and Methods

This was a cross sectional study, evaluating patients with glaucoma, cataract and age-related macular degeneration (AMD) from the Hospital das Clínicas – University of Campinas – Brazil. This study was approved by the Ethics Committee of the University of Campinas and adhered to the tenets of the Declaration of Helsinki. Subjects underwent a comprehensive ophthalmic examination, including Snellen best corrected visual acuity, slit-lamp biomicroscopy, intraocular pressure (IOP) measurement using Goldmann applanation tonometry, gonioscopy and dilated fundoscopy examination using a 78-
diopter lens. Subjects underwent standard automated perimetry, using the 24-2 Swedish Interactive Threshold Algorithm (SITA) Standard (Humphrey, Carl Zeiss Meditec, Inc., Dublin, CA, USA) and also retinal imaging with nonmyd WX3D (Kowa, Japan).

Three different groups were investigated. Glaucoma patients were required to have repeatable (at least 2 consecutive) abnormal SAP results with corresponding glaucomatous optic nerve damage in at least one eye. An abnormal SAP result was defined as a pattern standard deviation with $P < 0.05$, and/or Glaucoma Hemifield Test results outside normal limits. Cataracts were classified according to the Lens Opacities Classification System III (LOCS III) based on findings from slit lamp examination.[19]

For AMD, we applied the Clinical Age-Related Maculopathy Staging system, which divides patients into 5 mutually exclusive categories based on slit-lamp assessment of drusen, retinal pigment epithelial irregularities, geographic atrophy, retinal pigment epithelial detachment, and choroidal neovascularization.[20, 21]

**NEI VFQ-25 Questionnaire**

The NEI VFQ was originally developed with 51 items to capture the influence of vision impairment on multiple dimensions of health related QoL, such as emotional status and social functioning. Mangione et al validated a shorter and reliable version with 25 items.[7] We assessed vision-related QoL using a Brazilian Portuguese version of the NEI VFQ-25 questionnaire.[7] This version was developed by Simao et al in 2008 and was initially tested for in a set of ophthalmic patients and healthy controls.[17] The NEI VFQ-25 consists of 25 questions measuring overall vision,
difficulty with near-vision and distance activities, ocular pain, driving difficulties,
limitations with peripheral vision and color vision, social functioning, role limitations,
dependency and mental health symptoms. The questionnaire was interview-administered.

**Rasch analysis**

Rasch analysis was performed to obtain final estimates of “person measures,”
which can be used to express where each respondent falls on a linear scale representing
the degree of impairment as measured by the NEI VFQ-25.[22, 23] Rasch analysis was
performed using Andrich rating-scale models to obtain the estimates of the required
ability of each item, perceived ability of each subject, and the thresholds for each
response category.[14] The unit of those estimated measures is called a logit (log-odds
unit), which is calculated as the log-odds ratio of the probability that a participant will
select a particular rating category in an item over 1 minus the same probability. The logit
values place patients according to their abilities and items according to their difficulties
on the same linear interval scale. [24]

Person and item measures were examined for fit to the Rasch model using infit
and outfit item fit statistics.[8] To test the hypothesis that the NEI VFQ-25 measures a
single underlying construct, we initially evaluated the fit statistics, which were recorded
as mean square standardized residuals (MNSQ); The fit of the Rasch model was
evaluated with the infit and outfit statistics. Values between 0.7 and 1.3 are considered
acceptable for MNSQ values of infit and outfit.[25] After checking fit statistics, we
conducted a principal components analysis of the residuals (difference between the observed and expected responses).\[26\] Data are considered unidimensional if most of the variance is explained by the principal component and there is no significant explanation of the residual variance by the contrasts to the principal component. In general, to be considered unidimensional, the variance of the principal component should be $>60\%$.\[8, 26\] Furthermore, the unexplained variance by the contrasts should be $<2$ Eigenvalue units.\[26\]

We also evaluated differential item functioning, which assesses whether the items have different meanings for different groups in the sample. The raw differences in item calibration between groups were examined to identify differential item functioning. The differential item functioning was considered absent if it was less than 0.50 logits, minimal but probably inconsequential if it ranged between 0.50 and 1.0 logits, and notable if it was $>1.0$ logit.\[12, 27\]

The person separation index is the ratio of the variance in the person measures for the sample to the average error in estimating these measures. It is a measure of how broadly the persons could be distinguished into statistically distinct levels. The person separation reliability coefficient describes the reliability of the scale to discriminate between the persons of different abilities.\[12\] A person separation index of $\geq 2.0$ or a reliability value of $\geq 0.8$ represents the minimum acceptable level of separation.\[12, 25\]

**Demographic, Clinical and Socio-economic Variables**

Socio-economic questionnaires were also administered along with the NEI VFQ-25 to all patients. These questionnaires contained a survey about demographics, history of
ocular and medical conditions, marital status, degree of education and income. For comorbidities, we investigated the presence or history of the following conditions: diabetes mellitus, arthritis, high blood pressure, heart disease, depression, asthma, and cancers. A simple summation score was used to create a comorbidity index.[28] As these variables could potentially affect patient perceptions about vision-related QOL, they were included as covariates factors to investigate their association with the final Rasch-calibrated NEI VFQ-25 scores. These variables were categorized for inclusion in the univariate and multivariate models as race (African American [yes/no]), employment (yes/no), marital status (married [yes/no]), degree of education (at least high school degree [yes/no]) and income (less than $25,000/year [yes/no]). Visual acuity was measured using an Early Treatment Diabetic Retinopathy (ETDRS) chart and logMAR measurements were used in the analyses evaluating better and worse eye.[29] For patients with visual acuity measures of “counting fingers” (CF), “hand motion”, “light perception” and “no light perception” (NLP), we converted into quantitative measurements such as logMAR, as suggested by Schulze-Bonsel. [29]

**Statistical Analysis**

Descriptive statistics included mean and standard deviation for normally distributed variables. We investigated the relationship between final Rasch-calibrated NEI VFQ-25 scores with socioeconomic and clinical variables (gender, race, education, income, marital status, visual acuity in logMAR, presence of low vision and mean deviation from standard automated perimetry) using a linear regression model. Variables with P value < 0.2 were included in the final multivariable linear regression model.
Statistical analyses were performed using Winsteps 3.81.0 (Chicago, IL) and STATA v. 13 (StataCorp, College Station, TX). The alpha level (type I error) was set at 0.05.

**Results**

The study included 104 patients with cataract, 65 cases with glaucoma and 83 cases with AMD. Table 1 presents demographic variables of the studied population. Mean age was 70.7 ± 9.9 years, with 143 female (56.7%) and 109 male patients (43.2%). Most of them were retired (74%). Table 2 describes the clinical variables of the patients. Mean visual acuity in the better eye was 0.47 logMAR and 1.17 logMAR in worse eye. There were 62 patients (24.6%) with low vision (counting fingers, hand motion, light perception or loss of light perception in one or both eyes).
Table 1. Demographic characteristics of all patients included in the study.

| Parameters                  | Total subjects (n = 252) |
|-----------------------------|-------------------------|
| Age (years)                 |                         |
| Mean ± SD                   | 70.7± 9.9               |
| Range                       | 30 to 103               |
| Gender, n (%)               |                         |
| Male                        | 109 (43.2%)             |
| Female                      | 143 (56.7%)             |
| Race, n (%)                 |                         |
| Caucasian                   | 204 (81.2%)             |
| African-American            | 44 (17.5%)              |
| Job status (%)              |                         |
| Employed                    | 44 (18.1%)              |
| Unemployed                  | 19 (7.8%)               |
| Retired                     | 180 (74.0%)             |
| Marital status (%)          |                         |
| Married                     | 119 (69.5%)             |
| Single                      | 25 (14.6%)              |
| Widowed                     | 14 (8.1%)               |
| Divorced                    | 13 (7.6%)               |
| Education (%)               |                         |
| Illiterate                  | 2 (0.8%)                |
| Elementary school           | 137 (56.6%)             |
| High school degree          | 58 (23.9%)              |
| College degree              | 8 (3.2%)                |
| Income per month (%)        |                         |
| Lower than US$414.00        | 81 (48.2%)              |
| Between US$414.00 and US$2,073.00 | 68 (40.4%)         |
| Between US$2,073.00 and US$4,147.00 | 17 (10.1%)       |
| Higher than US$4,147.00     | 2 (1.1%)                |
| Comorbidity Index (%)       |                         |
| Zero                        | 71 (28.9%)              |
| One                         | 109 (44.4%)             |
| Two                         | 58 (23.6%)              |
| Three                       | 6 (2.4%)                |
Table 2. Clinical characteristics of all patients included in the study.

| Parameters                                                                 | Total subjects (n = 252) |
|---------------------------------------------------------------------------|--------------------------|
| LogMar Visual acuity (better eye) Mean ± SD                               | 0.47 ± 0.39              |
| LogMar Visual acuity (worse eye) Mean ± SD                               | 1.17 ± 0.74              |
| SAP MD from glaucoma (better eye) (dB) Mean ± SD                         | -4.26 ± 3.85             |
| SAP MD OS from glaucoma (worse eye) (dB) Mean ± SD                       | -10.77 ± 9.38            |
| Low vision, n (%)                                                         | 62 (24.6%)               |

SD: standard deviation; SAP: standard automated perimetry; MD: mean deviation; OD: right eye; OS: left eye.

Rasch Analysis

Results of Rasch analysis are shown in Table 3. Four Three items (Q4, Q1749, and Q1924 and Q25) were found to misfit (from subscales: general health, mental health, ocular pain, ocular pain and role limitations) with infit and/or outfit mean scores >1.3. Figure 1 shows a scatterplot with the items with misfit. Principal components analyses of the residuals from Rasch analysis can also be used to check the assumption of unidimensionality.[30] In order to determine whether the assumption of unidimensionality is valid, the variance explained by the Rasch factor (the underlying construct) should be 4 times greater than that of the first principal component in the residuals and the variance explained by the Rasch factor should be greater than 60%.[31]
Fig 1. Scatterplot of infit versus outfit statistics for item measures estimated from responses to items in the National Eye Institute Visual Function Questionnaire (NEI VFQ-25). The box bounds the 1.3 unacceptable limits, highlighting the misfitting items inside the box.

Table 3. Fit Statistics using Rasch Analysis with respective Items and Subscales from National Eye Institute Visual Function Questionnaire (NEI VFQ-25).

| Questions                  | Items             | Subscales      | Measure | Infit MNSQ | Outfit MNSQ |
|---------------------------|-------------------|----------------|---------|------------|-------------|
| Q1 General health         | General health    | General health | -0.19   | 1.09       | 1.12        |
| Q2 General vision         | General vision    | General vision | -0.30   | 0.62       | 0.77        |
| Q3 Worry about eyesight   | Mental health     | Mental health  | -0.46   | 1.05       | 1.21        |
| Q4 Pain around eyes       | Ocular pain       | Ocular pain    | 0.41    | 1.58       | 2.03        |
| Q5 Reading normal newsprint | Near vision     | Near vision    | -0.22   | 0.93       | 0.93        |
| Q6 Seeing well up close   | Near vision       | Near vision    | 0.07    | 0.89       | 0.84        |
| Q7 Finding objects on crowded shelf | Near vision | Near vision | 0.40 | 0.79 | 0.73 |
| Q8 Street signs           | Distance vision   | Distance vision| 0.13  | 0.91       | 0.92        |
| Q9 Going downstairs at night | Distance vision | Distance vision| 0.30  | 0.79       | 0.75        |
| Q10 Seeing objects off to side | Peripheral vision | Peripheral vision | 0.36  | 0.72       | 0.68        |
| Q11 Seeing how people react | Social function  | Social function | 0.91  | 0.90       | 0.61        |
| Q12 Matching clothes      | Color vision      | Color vision   | 0.79    | 0.85       | 0.84        |
| Q13 Visiting others       | Social function   | Social function | 0.56  | 1.05       | 0.88        |
| Q14 Going out to movies/plays | Distance vision | Distance vision | 0.26  | 1.19       | 1.24        |
| Q17 Accomplish less       | Role limitations  | Role limitations| -0.37 | 1.40       | 1.41        |
| Q18 Limited endurance     | Role limitations  | Role limitations| -0.42 | 0.88       | 0.83        |
| Q19 Amount of time in pain | Ocular pain       | Ocular pain    | -0.18   | 1.65       | 1.75        |
| Q20 Stay home most of the time | Dependency   | Dependency     | -0.32   | 0.89       | 0.83        |
| Q21 Frustrated            | Mental health     | Mental health  | -0.51   | 1.06       | 1.02        |
| Q22 No control            | Mental health     | Mental health  | -0.32   | 1.01       | 0.92        |
| Q23 Rely too much on others’ words | Dependency | Dependency     | -0.51   | 1.07       | 0.87        |
| Q24 Need much help from others | Dependency | Dependency     | -0.40   | 0.96       | 0.87        |
| Q25 Embarrassment         | Mental health     | Mental health  | -0.51   | 1.30       | 0.99        |

MNSQ: mean square
For the current work, the principal component analysis of the residuals showed that the variance explained by the principal component was comparable for empirical calculation (50.9%) and by the model (51.9%). This suggests that the questionnaire was not unidimensional. Moreover, the unexplained variance explained by the first contrast was 3.38 eigenvalue units and the second contrast was 2.56 eigenvalue units with no further contrasts exceeding 2.0 eigenvalue units. These findings suggested the presence of a second dimension in the scale. Eight items loaded (correlation > 0.4) positively onto the first contrast. We analyzed the principal components/contrast plots of item loadings and found items belonging to different clusters with high positive loadings (correlation > 0.4) onto the first contrast. We also identified 3 different clusters and exclude items from General health (Q1), Mental Health (Q3, Q21, Q22, and Q25), Role limitations (Q18), Dependency (Q20, Q23, and Q24), that belonged to a secondary dimension underlying the first contrast, which could be biasing the person measures, and belonged to: general health (Q1), mental health (Q3, Q21, and Q22), role limitations (Q17 and Q18) and dependency (Q20 and Q23). This suggests that these eight-nine items cannot be grouped with other items in the scale to measure a single latent trait (visual functioning). These items are probably related to a social-emotional component. Of note, in the current sample, 187 patients (74.4%) answered that they were
not currently driving (Q15). Within this group, 158 patients (84.5%) reported that they never had driven (Q15a). Therefore questions related to driving were not assessed in the Rasch Analysis due to missing data.

Differential item functioning was tested for some of the variables from Table 1 and Table 2, such as: age, gender, race, job status, marital status, education, level of income, low vision and type of eye disease (cataract, glaucoma and AMD). There was no differential item functioning for any of the variables mentioned. These results suggest that items could be interpreted similarly across subgroups of the sample.

After excluding items that were considered misfitted (Q4, Q419, Q1724 and Q1925) and also those items with high loadings on the principal component analysis of the residuals, such as: General health (Q1), Mental Health (Q3, Q21, Q22 and Q25), Role limitations (Q18), Dependency (Q20, Q23 and Q24), general health (Q1), mental health (Q3, Q21 and Q22), role limitations (Q18) and dependency (Q20 and Q23), we were able to isolate items from the NEI VFQ-25, related only to the visual function component. According to Table 4, no items were misfitted. We also performed a principal component analysis of the residuals of the revised version of the NEI VFQ-25 (items related to visual function). The final variance of the principal component was 61.2% and the unexplained variance by the contrasts is 1.64 eigenvalue units, showing no evidence of multidimensionality (Table 5). The mean (± SD) of the person measures was -3.02 ± 1.09 logits. In figure 2, we showed the Wright item-person maps of the revised version of the NEI VFQ-25 (only items related to visual function). We investigate targeting using Wright person-item maps (Figure 2). We found that our sample did not ideally matched items for both original versions of NEI VFQ-25. Even after removal of misfitting items,
most of the items (right-side, top of the scale) were not able to cover people with most visual ability (left side, bottom of the scale). The separation index for person measures was 2.44, with reliability of 0.86. We also reported the psychometric properties of the socioemotional component of the NEI VFQ-25 (Table 5).

**Fig. 2.** Wright item-person maps related to visual function of the revised version of the National Eye Institute Visual Function Questionnaire (NEI VFQ-25). The left-hand column locates the person ability measures along the variable. The right-hand column locates the item difficulty measures along the variable.

**Table 4.** Fit Statistics from Rasch Analysis with respective Items and Subscales using the only item related to visual function of the National Eye Institute Visual Function Questionnaire (NEI VFQ-25).

| Questions | Items                          | Subscales     | Measure | Infit MNSQ | Outfit MNSQ |
|-----------|--------------------------------|---------------|---------|------------|-------------|
| Q2        | General vision                 | General vision| -1.13   | 0.77       | 0.92        |
| Q5        | Reading normal newsprint       | Near vision   | -1.06   | 1.10       | 1.08        |
| Q6        | Seeing well up close           | Near vision   | -0.47   | 0.99       | 0.99        |
| Q7        | Finding objects on crowded     | Near vision   | 0.23    | 0.90       | 0.84        |
| Q8  | Street signs | Distance vision | -0.34 | 0.98 | 0.96 |
| Q9  | Going downstairs at night | Distance vision | 0.02 | 0.90 | 1.00 |
| Q10 | Seeing objects off to side | Peripheral vision | 0.14 | 0.75 | 0.71 |
| Q11 | Seeing how people react | Social function | 1.17 | 1.00 | 0.88 |
| Q12 | Matching clothes | Color vision | 0.97 | 0.88 | 1.04 |
| Q13 | Visiting others | Social function | 0.54 | 1.25 | 1.15 |
| Q14 | Going out to movies/plays | Distance vision | -0.07 | 1.21 | 1.22 |

| Components | Visual Function | Socioemotional |
|------------|----------------|----------------|
| Items in Scale (n) | 11 | 8 |
| Misfitting Items (n) | None | 2 (Q1 and Q3) |

Table 5. Rasch Analysis Fit Statistics of the Visual Function and Socioemotional Components from the National Eye Institute Visual Function Questionnaire (NEI VFQ 25).
We also investigated the association between demographic and clinical variables with the final scores of the revised version of the NEI VFQ-25. Within the clinical and demographic variables, there was a statistical relationship with the Rasch-calibrated scores in NEI VFQ-25 for the following variables in univariable models: visual acuity in the better eye ($P<0.001$), visual acuity in the worse eye ($P<0.001$), patients with low vision ($P<0.001$), gender ($P<0.001$), marital status ($P=0.001$), employment status ($P=0.019$), education level ($P<0.001$) and comorbidity index ($P=0.003$). In a multivariable analysis, only 2 variables remained statistically significant: visual acuity in the better eye ($P<0.001$) and education level ($P=0.002$).

**Discussion**

In the current study, we investigated the psychometric properties of the Brazilian Portuguese version of the NEI VFQ-25 using Rasch analysis. Our results showed that the
NEI VFQ-25 does not seem to be an unidimensional instrument; that is, it does not measure a single latent construct (quality of life related to visual function).[11] Although most items on the NEI VFQ-25 tap the construct of visual functioning, our results indicated that other items belonged to a different construct, namely socio-emotional component, corroborating findings from previous studies.[12, 13]

Unidimensionality of an instrument can be assessed by examining the fit statistics and principal component analysis of the residuals. Ideally items should have MNSQ values between 0.7 and 1.3. Items with MNSQ lower than 0.7 suggest a high level of predictability in the responses, indicating redundancy, [25] whereas values higher than 1.3 show an unacceptable level of noise in the responses. According to Table 3, four items (Q4, Q19, Q24 and Q25) were found to misfit. Those items belonged to the subscales of mental health, ocular pain and role limitations. In Figure 1 we can observe a scatterplot with the items that we considered misfitted.

When the variance of the principal component is considered high (60% or greater), there is a low likelihood of additional components[13]. In the current study, the principal component analysis of the residuals showed that the variance explained by the principal component was 51.9%. In addition to that, if the variance explained by the principal component for the real data and the model are similar, the chances of finding additional constructs are low. When patterns within variance are unexplained by the principal component, a second construct can be measured. This finding is reported by the first contrast in the residuals. According to previous study, a contrast should have an eigenvalue higher than 2.0 to be considered as an evidence of a second construct being greater than the magnitude seen with random data[13]. Our initial analysis showed a first
contrast with 3.38 eigenvalue units, suggesting that the Brazilian Portuguese version of the NEI VFQ-25 was not unidimensional. In addition to that, we also need to exam the principal component analysis of the residuals as a second test for unidimensionality. A high level of variance accounted for by the principal component leads to a low likelihood of additional components; a variance of 60% or greater is considered good. In the current study, the principal component analysis of the residuals showed that the variance explained by the principal component was 51.9%. Moreover, the unexplained variance explained by the first contrast was 3.38 eigenvalue units. The first contrast in the residuals reports whether there are patterns within variance that are unexplained by the principal component, which suggests a second construct is being measured.[13] According to previous studies, the current study applied the criterion that the contrast should have an eigenvalue higher than 2.0 to be considered evidence of a second construct because this would be greater than the magnitude seen with random data. Thus, our analysis showing the first contrast with a 3.38 eigenvalue units, suggests that the Brazilian Portuguese version of the NEI VFQ-25 was not unidimensional.

The loading of items onto the contrasts allows identification of which items tap different constructs. In our analysis, eight-nine items loaded positively onto the first contrast with a correlation higher than 0.4. These items belonged to the following subscales: General health (Q1), Mental Health (Q3, Q21, Q22 and Q25), Role limitations (Q18), Dependency (Q20, Q23 and Q24), general health (Q1), mental health (Q3, Q21 and Q22), role limitations (Q17 and Q18) and dependency (Q20 and Q23). This suggests that these eight-nine items cannot be grouped with other items in the scale to measure a single latent construct, such as QoL related to visual function. The purpose of using
principal component analysis and inspecting contrast plots is to find patterns in the
dataset and discover groups of items that share the same patterns of unexpectedness,
which could represent a secondary dimension, proving that the instrument is not
unidimensional.

We were able to isolate items from the NEI VFQ-25, related only to a visual
function component, after excluding items that were considered misfitted and also those
items with high loadings on the principal component analysis of the residuals. When we
re-examined the fit statistics of this revised version of the NEI VFQ-25, no items were
misfitted (Table 4). Moreover, the final variance of the principal component was 61.2%
and the unexplained variance by the first contrast was 1.64 eigenvalue units (Table 5).
These results suggest that this revised version of the NEI VFQ-25 showed no evidence of
multidimensionality.

The Wright person-item map revealed that items did not adequately covered all
spectrum of visual abilities. In fact, most of uncovered percentage of patients represents
persons with more visual ability (Figure 2). This may be explained by our sample did not
include enough people with significant visual impairment. Simao et al used a “Factor
analysis” and concluded that almost all subscales of NEI VFQ-25 belong to the same
underlying dimension. However, careful analysis of their data suggests some evidence of
multidimensionality.[17] For example, they showed that most of the subscales from the
Portuguese version of the NEI VFQ-25 were influenced by central vision correlated with
the first factor, while the “General vision”, “Ocular pain” and “Peripheral vision”
subscale were included in a second factor. We were able to find a second construct more related to a socio-emotional component formed by subscales such as: “General health”, “mental health”, “role limitations” and “dependency”, in contrast to central and peripheral vision constructs as highlighted in the previous study. This difference might be due to application of different types of analysis (Rasch as opposed to Factor Analysis).  

Factor Analysis assumes that distances on the scales are equal and the sum the responses of each item not taking into account item hierarchy. Rasch analysis can build a measure with items assuming a hierarchy level. When evaluating an instrument with the Rasch model, more fundamental evidence may be provided to justify the use of scale scores on an interval level. Distances on the scales developed by the Factor Analysis approach are interpreted as equal over the full range of the scale. The scale is treated as an interval scale based on ordinal level item scoring. In fact, Pesudovs et al investigated the psychometric properties of the NEI VFQ-25 with Rasch analysis in a group of patients with cataract and found that several subscales were not psychometrically sound. They concluded that the NEI VFQ-25 as an overall measure was flawed by multidimensionality. In addition, Marella et al performed a similar investigation with a group of low vision patients and also found that the NEI VFQ-25 is a better performing instrument when divided into two different scales, with items from General health (Q1), Mental Health (Q3, Q21, Q22 and Q25), Role limitations (Q18), Dependency (Q20, Q23 and Q24) belonging to a secondary dimension, corroborating the findings of our study.

Another important characteristic of a good instrument is that items function...
similarly for persons at the same level of ability. Differential item functioning was tested for the following variables: age, sex, race, job status, marital status, education, level of income, low vision and type of eye disease (cataract, glaucoma and AMD). Differential item functioning occurs when subgroups of people with comparable levels of ability respond differently to an item, which implies a response to some characteristic other than item difficulty. We were not able to find evidence of differential item functioning for any of the variables mentioned. Thus, our results suggest that items from the Portuguese version of the NEI VFQ-25 could be interpreted similarly across subgroups of the sample, including different eye diseases, such as cataract, glaucoma and AMD.

We found that worse visual acuity and patients with lower education level had lower Rasch-calibrated NEI VFQ-25 scores. Even though patients with AMD had lower Rasch-calibrated scores of NEI VFQ-25 compared to cataract and glaucoma patients, when adjusting for visual acuity, the correlation with different types of eye disease in the multivariable analysis was not statistically significant, implying that visual acuity may be a better predictor for vision related QoL in comparison to the underlying cause of the vision loss. In fact, associations between worse visual acuity and QoL have already been demonstrated.[7, 33] Moreover, previous work have suggested that poor educated patients might have higher levels of emotional distress (including depression, anxiety, and anger) and physical distress (including aches and pains and malaise), which could influence the responses of the QoL questionnaire.[34]

The current study has limitations. Even though Rasch analysis is becoming the gold standard for scoring patient-reported outcome measures in ophthalmology, a multilevel model that allows simultaneous analysis of different dimensions in a
multidimensional instrument could also be used. Our sample consisted of patients with cataract, glaucoma and AMD. Thus, future studies should investigate psychometric validity of the Rasch calibrated version of the NEI VFQ-25 in a sample with more varied range of eye diseases.

**Conclusion**

Our findings indicate that the Brazilian Portuguese version of the NEI VFQ-25 is not psychometrically optimal for assessing QoL related only to visual function. Rather, we found a second trait, described as a socioemotional component from results of the Rasch analysis. Thus, in order to obtain psychometrically valid constructs, both components with their respective subscales and items (visual functioning and socioemotional) should be analyzed separately. Future studies in Brazil including patients with different eye diseases are needed to substantiate our findings and evaluate the sensitivity of this calibrated version of the NEI VFQ-25.

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## POINT-BY-POINT RESPONSE FORM

**Manuscript #:** PONE-D-19-19847

**Manuscript title:** Psychometric Properties of the Portuguese Version of the National Eye Institute Visual Function Questionnaire-25

| Suggestion, Question, or Comment from Reviewer #1 | Author’s Response | Change in the Manuscript |
|---------------------------------------------------|-------------------|--------------------------|
| The authors investigate the psychometric properties of the Brazilian Portuguese version of the National Eye Institute Visual Function Questionnaire (NEI VFQ-25) in a group of patients with different eye diseases. This is an important topic, as no study has yet applied Rasch Analysis to the Brazilian Portuguese version of the NEI VFQ-25. The study is well designed, executed and reported. However, I have a few comments. | We thank the reviewer for the comments. | N/A |
| Material and Methods: Adding some subheading could improve flow and readability for the reader. | We have made the proper changes as suggested. | We have included a subheading for Rasch Analysis |
| Not all readers are familiar with the NEI VFQ-25. Could you please provide more information about the NEI VFQ-25 (how initially developed, how many response options, which scaling [Likert scaling?], subscales)? | We have changed the text and figure legend as suggested. | We have included the following sentence: “The NEI VFQ was originally developed with 51 items to capture the influence of vision impairment on multiple dimensions of health related QoL, such as emotional status and social functioning. Mangione et al validated a shorter and reliable version with 25 items.” |
| Targeting: Did you inspect the person-item map and calculated the difference between item and person means before revising the questionnaire? Knowing if the difficulty of the items adequately targets the ability | We have made the proper changes as suggested. | We have included this sentence in the Results section: “We investigate targeting using Wright person-item maps. We found that our sample did not ideally matched items for both original versions NEI VFQ-25.” |
| of the sample provides valuable information. | Even after removal of misfitting items, most of the items (right-side, top of the scale) were not able to cover people with most visual ability (left side, bottom of the scale).” |
|---|---|
| Figure 2: The mean person achievement measure is much lower than the mean item difficulty, suggesting a lack of items at the low-ability end. Could you please explain and describe that? This finding is completely counter-intuitive as most questionnaires struggle with items that are too easy, in particular in questionnaires trying to capture VRQOL. | We have made the proper changes as suggested. We have now included the following sentence in the Discussion section: “The Wright person-item map revealed that items did not adequately covered all spectrum of visual abilities. In fact, most of uncovered percentage of patients represents persons with more visual ability (Figure 2). This may be explained by our sample did not include enough people with significant visual impairment.” |
| Table 2: Does the SAP MD values only refer to glaucoma patients or to the overall sample? | We thank the reviewer for the comments. The SAP MD values refer only to glaucoma patients. |
| Could you please add more information on visual ability of the participants? Please report n/% of the sample in the categories none/mild/moderate/severe visual impairment. | We thank the reviewer for the comments. In table 2 we have the information that 24.6% of the sample had low vision in one or both eyes. |
| Line 252: The authors say, that four items were found to misfit with Infit and/or Outfit MNSQ values <0.7 or >1.3. In Table 3 Infit and Outfit MNSQ values for Q24 are within these values, so why was this item found to misfit? Same for Q25. | We thank the reviewer for the comments. We have reviewed the manuscript and fixed the error. “Three items (Q4, Q17, and Q19) were found to misfit (from subscales: mental health and role limitations).” |
| Line 226: The authors say, that they investigated the relationship between final Rasch-calibrated NEI VFQ-25 scores with socioeconomic variables using a linear regression | We thank the reviewer for the comments. We have now uploaded the table as requested. |
model. Could you please provide the results in a table in the supplement to see raw and adjusted effects?

Most of the readers might not be familiar with Rasch analysis, so please explain in more detail the factor analysis/factor loading you used to assess unidimensionality of the scale. Otherwise it might not be easy to follow why items Q1, Q3, Q21, Q22, Q17, A18, Q20 and Q23 were excluded?

We thank the reviewer for the suggestions.

We have now included this sentence in the Discussion section to facilitate the reader’s understanding. “The purpose of using principal component analysis and inspecting contrast plots is to find patterns in the dataset and discover groups of items that share the same patterns of unexpectedness, which could represent a secondary dimension, proving that the instrument is not unidimensional.”

10. Please cite additional literature, which also reports the NEI-VFQ to be multidimensional.

We thank the reviewer for the suggestions.

We have now the following references regarding multidimensionality of the NEI VFQ-25:
12. Marella M, Pesudovs K, Keefe JE, O’Connor PM, Rees G, Lamoureux EL. The psychometric validity of the NEI VFQ-25 for use in a low-vision population. Invest Ophthalmol Vis Sci. 2010;51(6):2878-84. doi: 10.1167/iovs.09-4494. PubMed PMID: 20089878.
13. Pesudovs K, Gothwal VK, Wright T, Lamoureux EL. Remediating serious flaws in the National Eye Institute Visual Function Questionnaire. J Cataract Refract Surg. 2010;36(5):718-32. doi: 10.1016/j.jcrs.2009.11.019. PubMed PMID: 20457362.
15. Kovac B, Vukosavljevic M, Djokic Kovac J, Resan M, Trajkovic G, Jankovic J, et al. Validation and cross-cultural adaptation of the National Eye Institute Visual Function
Line 39: Typing error/ double word: “National Eye Institute Visual Questionnaire (NEI VFQ-25) questionnaire”

| Suggestion, Question, or Comment from Reviewer #2 | Author’s Response | Change in the Manuscript |
|--------------------------------------------------|-------------------|-------------------------|
| The purpose of this manuscript is to investigate the psychometric properties of the Brazilian Portuguese version of the National Eye Institute Visual Function Questionnaire (NEI VFQ-25) questionnaire in a group of patients with different eye diseases by Rasch analysis. However, The authors found that Portuguese version of the NEI VFQ-25 is not a unidimensional instrument in measuring psychometric properties. Although they suggest that analyzing both visual function and socio-emotional components separately may be a valid method, they did not test the validity of this method. In addition, some mistakes in grammar was found in the manuscript. | We thank the reviewer for the comment. | We have corrected the grammar errors in the text. |

In this paper, Abe et al. investigated the psychometric properties of the Brazilian

| Suggestion, Question, or Comment from Reviewer #3 | Author’s Response | Change in the Manuscript |
|--------------------------------------------------|-------------------|-------------------------|
| In this paper, Abe et al. investigated the psychometric properties of the Brazilian | We thank the reviewer for the comment. | N/A |
Portuguese version of the National Eye Institute Visual Function Questionnaire-25. They found the Portuguese version of NEI VFQ-25 is not a unidimensional instrument, and suggested the visual functioning and socio-emotional components should be analyzed separately. In general, the paper is well written and in a good quality. The study is well designed, the data are convincing, the analysis is cogent.

In the methods part, the author may want to elaborate how the NEI VFQ-25 questionnaires were conducted. Were they self-administered or interviewer-administered?

We thank the reviewer for the suggestion. We have included the following sentence: “The questionnaire was interview-administered.”

In the methods part (line 206), “Socio-economic questionnaires were also administered along with the NEI VFQ-25 to all patients.” A sample of this questionnaire should be attached to this manuscript, preferably as supplementary materials.

We thank the reviewer for the comment. We have now attached the socio-economic questionnaire as supplementary material.

3. In the results part (line 252), “Four items (Q4, Q19, Q24 and Q25) were found to misfit (from subscales: general health, mental health, ocular pain and role limitations) with infit and/or outfit mean scores >1.3.”. However, from Table 3, the infit MNSQ and outfit MNSQ of Q24 are 0.96 and 0.87 respectively, and are both less than 1.3.

We thank the reviewer for the comment. We have reviewed the manuscript and fixed the error. “Three items (Q4, Q17, and Q19) were found to misfit (from subscales: mental health and role limitations).”

4. As authors wrote in the intro (line 110-115), “Marella

We thank the reviewer for the comment. In the Discussion section we have included the following
and colleagues have suggested that the NEI VFQ-25 questionnaire does not seem to be unidimensional, and that the questionnaire items may actually be measuring two different underlying constructs, one related to visual functioning and another to socioemotional status.” It would be necessary for the authors to include the comparison between the findings from the present study with Marella et al.’s result.

| Suggestion, Question, or Comment from Reviewer #4 | Author’s Response | Change in the Manuscript |
|--------------------------------------------------|-------------------|--------------------------|
| This is an interesting finding. The authors investigated the psychometric properties of NEI VFQ-25 using Rasch analysis in a population of Brazilian patients with a variety of eye diseases. They found that the Brazilian Portuguese version of the NEI VFQ-25 is not psychometrically optimal for assessing QoL related only to visual function. Moreover, they also observed a second... | We thank the reviewer for the comment. | N/A |

We thank the reviewer for the comment. The work from Pesudovs included only patients with cataract. Our sample included also patients with glaucoma and AMD. The variety of eye diseases in our sample might have influenced the results when evaluating fit performance.

In addition, Marella et al performed a similar investigation with a group of low vision patients and also found that the NEI VFQ-25 is a better performing instrument when divided into two different scales, with items from General health (Q1), Mental Health (Q3, Q21, Q22 and Q25), Role limitations (Q18), Dependency (Q20, Q23 and Q24) belonging to a secondary dimension, corroborating the findings of our study. [12]
trait, described as a socioemotional component from results of the Rasch analysis. Overall, the authors have described the experimental design and knowledge gaps to be generally filled with this study. The results have been generally presented in a reasonable and expected approach with solid statistical analysis.