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Introduction

The present work is inspired by the thought of having a single index to scale the hearing aid (HA) benefit from self-reported questionnaires. Previous studies have shown that speech understanding in noisy environments is one of the most desired improvements sought by hearing aid users [1, 2]. The perceived HA benefit thus can depend on the facilitation of everyday communication in challenging environments by the HA. This should also ideally reflect in self-reported questionnaires responses recorded in the BEAR project. Single index scale would facilitate the identification of a sub-population, if there exist, with a low-compensation benefit from the usage of hearing aid.

The self-reported questionnaire responses recorded during the follow-up visit 2 months after the initial fit, show a stronger correlation (Figure 1) of 15D question 3 related to speech understanding, to the 17 questions of SSQ, and three questions from IOI-HA (Question 3, 5, and 6), which were also part of the same survey (Figure 2). Further, a composite single value index created from speech-related questions (SRQ) that are part of the survey can be a good representation of the perceived hearing aid benefit.

Figure 1. Correlation matrix for 15D, SSQ (17 questions) and IOI-HA recorded during the follow-up visit 2 months after the initial fitting of the hearing aid.

Methods

The principal component analysis is used as the basis to form a composite index related to speech understanding from the self-reported questionnaires. This approach is well established in constructing a composite socio-economic status index [3, 4].

Three sets of questions were selected for the study are:

- Speech Related Questions -Set 1: 15D-Question 3, IOI-HA (Question 3, 5, and 6), and SSQ Speech domain questions (Question 1, 4, 10, 11, and 12)

- Speech Related Questions -Set 2: 15D-Question 3, SSQ Speech domain questions (Question 1, 4, 10, 11, 12, and 14), SSQ Quality domain (Questions 14, 15, 16, 17)

- All questions of all three questionnaires (total 39 questions).

Only responses recorded from the follow-up visit (after 2 months of initial fit) were considered for the study.

DATA SORTING
The responses to the questions of interest in each set are extracted.

From a total of 1960 participants, participants with valid responses to all of the questions in the considered set are only included in the study (SRQ-Set1:N=1468,SRQ-Set2:N=1321,All Questions: N=996).

15D questions are applied with respective weight.

PCA
The data is standardized by scaling and centering before the analysis.

The factors scores, eigenvalues, and percentage contribution are saved from the result of the analysis.

INDEX
Principal components explaining up to 90% of variances are considered for deriving the index.

The index is derived using the below formula:

$$Index_i = \sum_{k=1}^{K} \frac{PC_k}{PC_{total}} * Factor\ Score_{ik}$$

i = Number of participants.
K = Number of principal components considered for the analysis.
PC_k = % of variance explained by the kth PC.
PC_{total} = % of total variance explained.
Factor Scoreik = Score[i] * loading[k].

Figure 2. The data was sorted and weights for 15D were applied before performing PCA, and calculation of composite single value index.
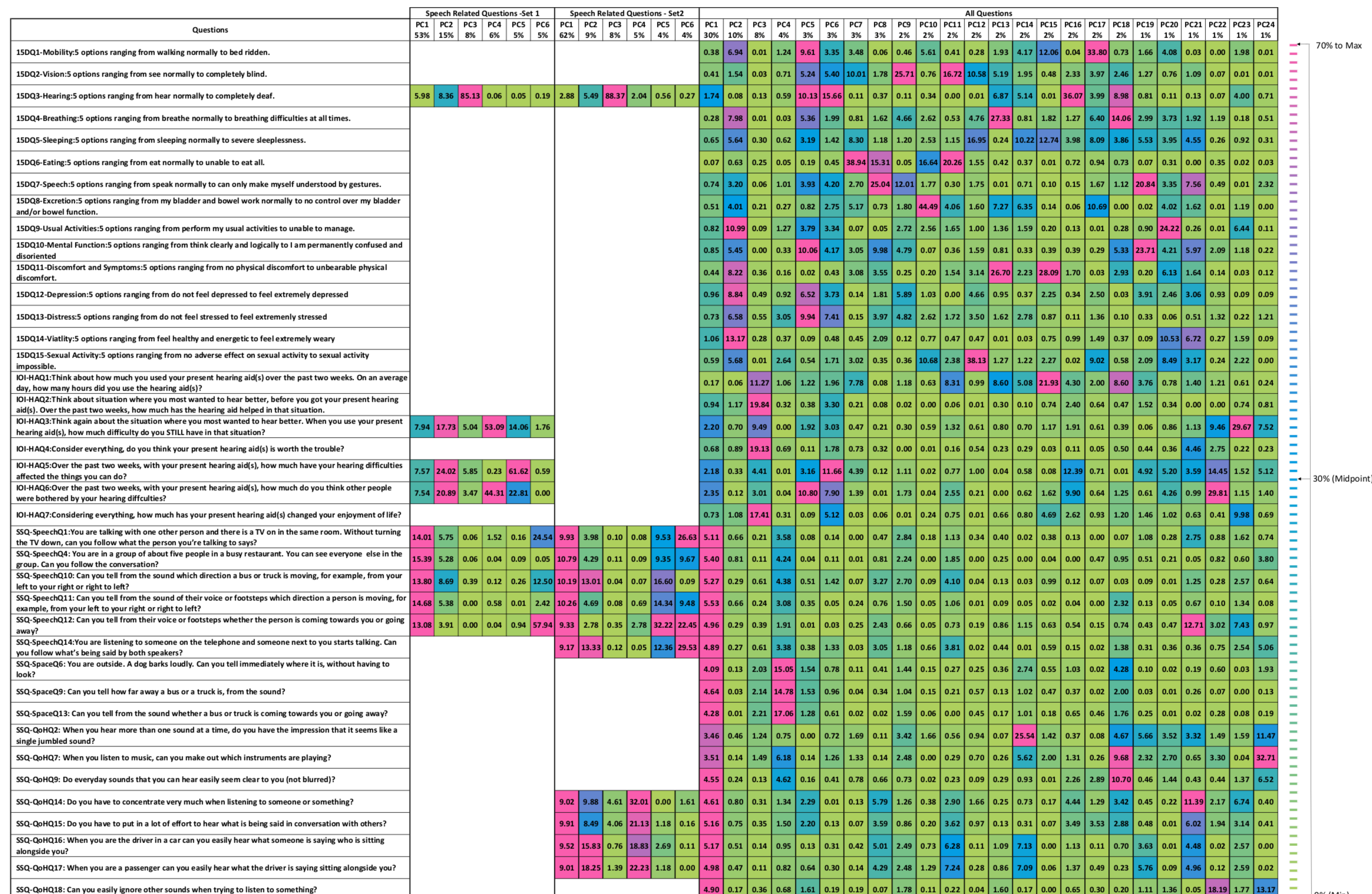
Results

Figure 3. The table shows PCA results for the three sets of questionnaires. The percentage contribution of each principal component (PC) is indicated in the second row of the header. The values in the fields below each PC are the percentage contribution of each question to that respective PC. From analysis of all questions, it can be seen 1) PC1 is clearly linked to speech understanding (SSQ answers), 2) PC2 is related to mental well-being (stress, discomfort, depression), 3) PC3 is most strongly related to hearing benefit (IOI-HA), whereas 4) PC4 may represent spatial dimensions of the hearing experience.
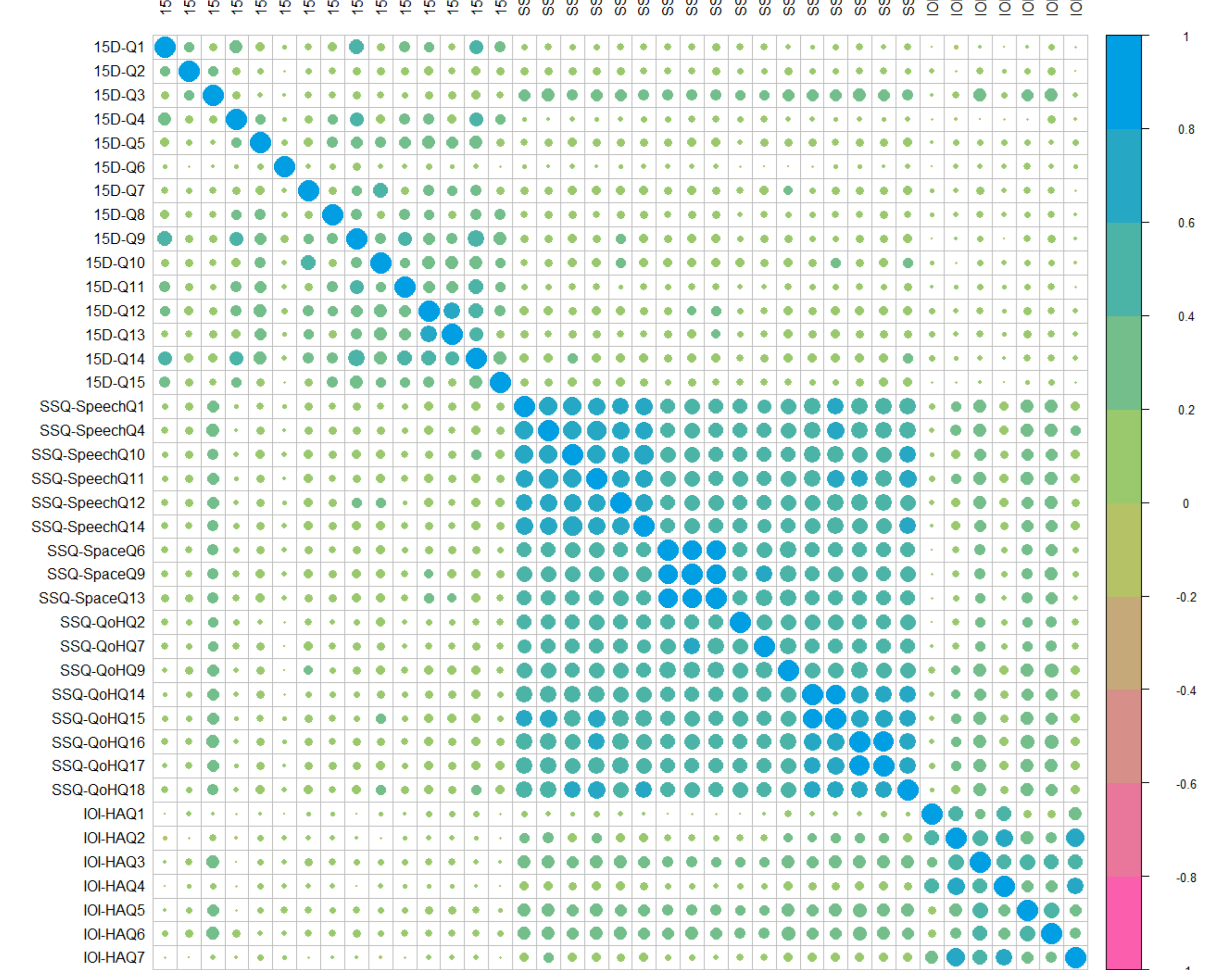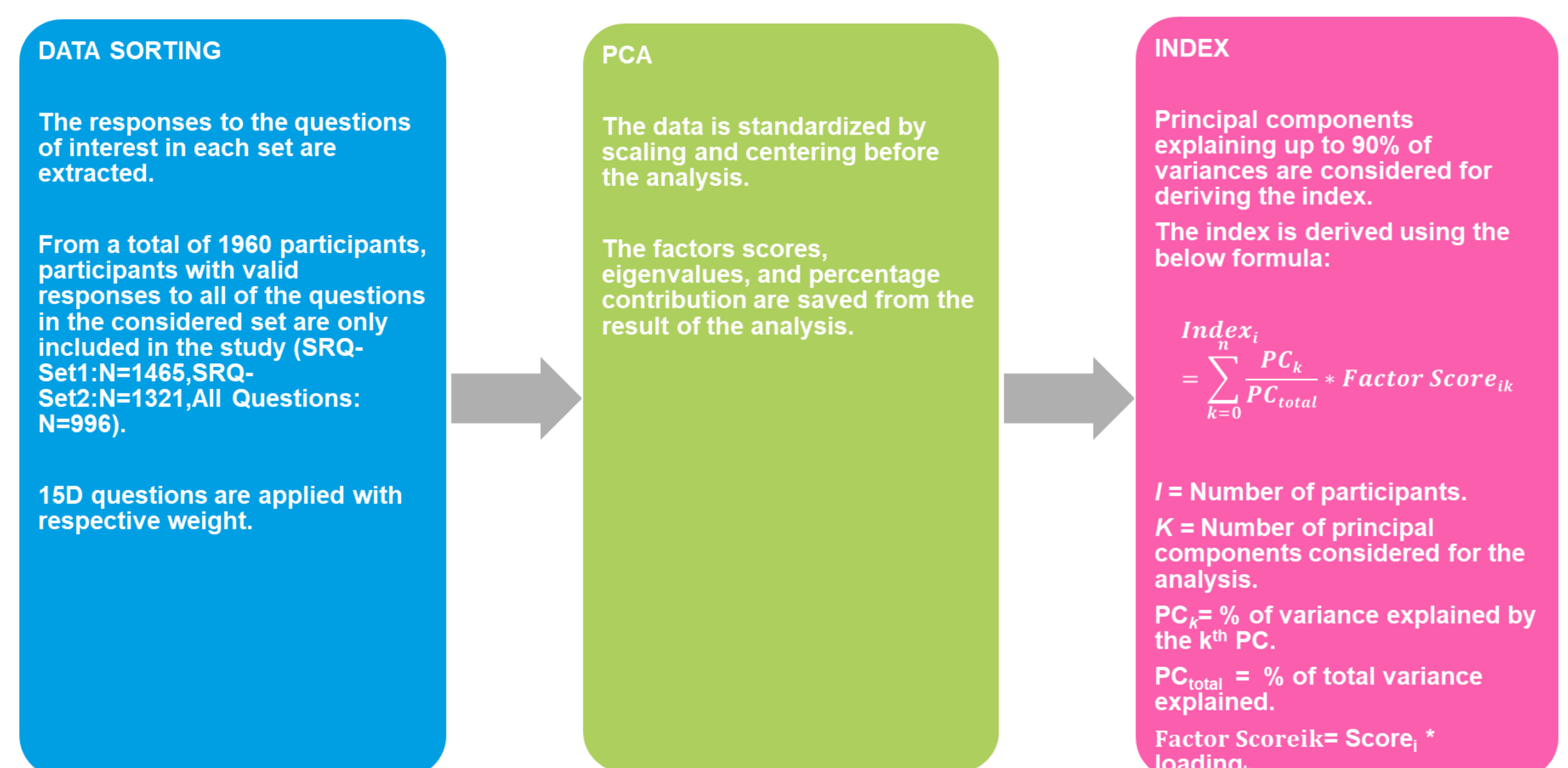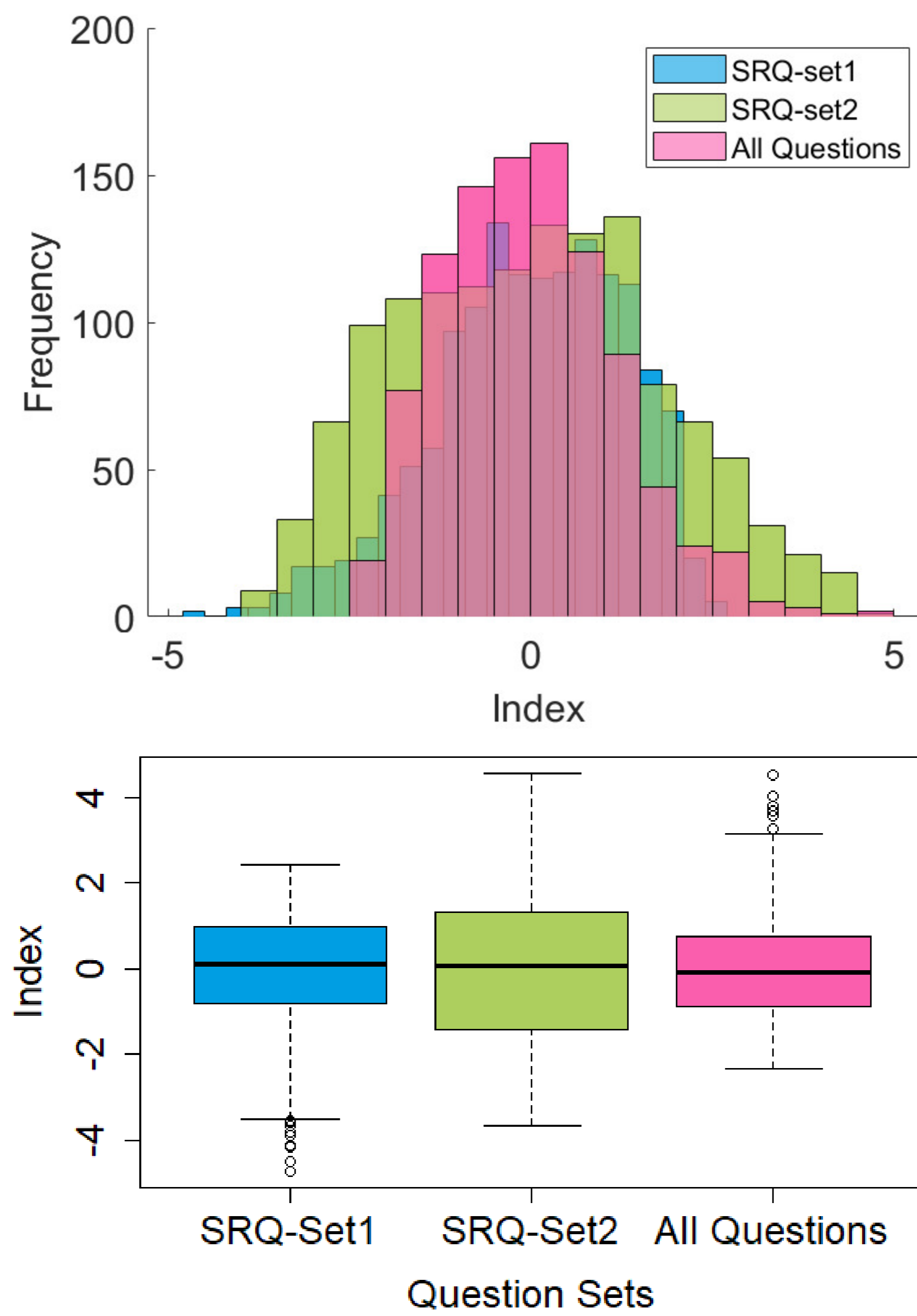

Figure 4. Top: The plot shows the histogram of the derived index from all three sets of questions. Bottom: The box plot with the median of the derived index and error bars showing the 95% confidence intervals. It can be seen that the median in all cases is close to the same level. An ANOVA showed no significant difference between the three sets of questions.

Figure 5. Top: The index derived from SRQSet1 plotted against the index derived using all 39 questions. The plot shows negative covariance (covariance coefficient: -1.31). Bottom: The index derived from SRQSet2 plotted against the index derived using all 39 questions. The plot shows positive covariance (covariance coefficient: 1.92).

Discussion

The results establish the relation of speech in the perceived benefit. The positive covariance of the index derived from speech specific questions to all questions supports this hypothesis.

The derived composite index can thus be used to define the sub-population with low compensation benefit from a speech-related function point of view. A negative index can be an indication of low aided benefit.

Further, the index can be regressed with other outcomes like aided speech intelligibility, compression parameters, word-recognition scores, and hearing aid usage time for having a stronger understanding of underlying factors defining low compensation benefit.
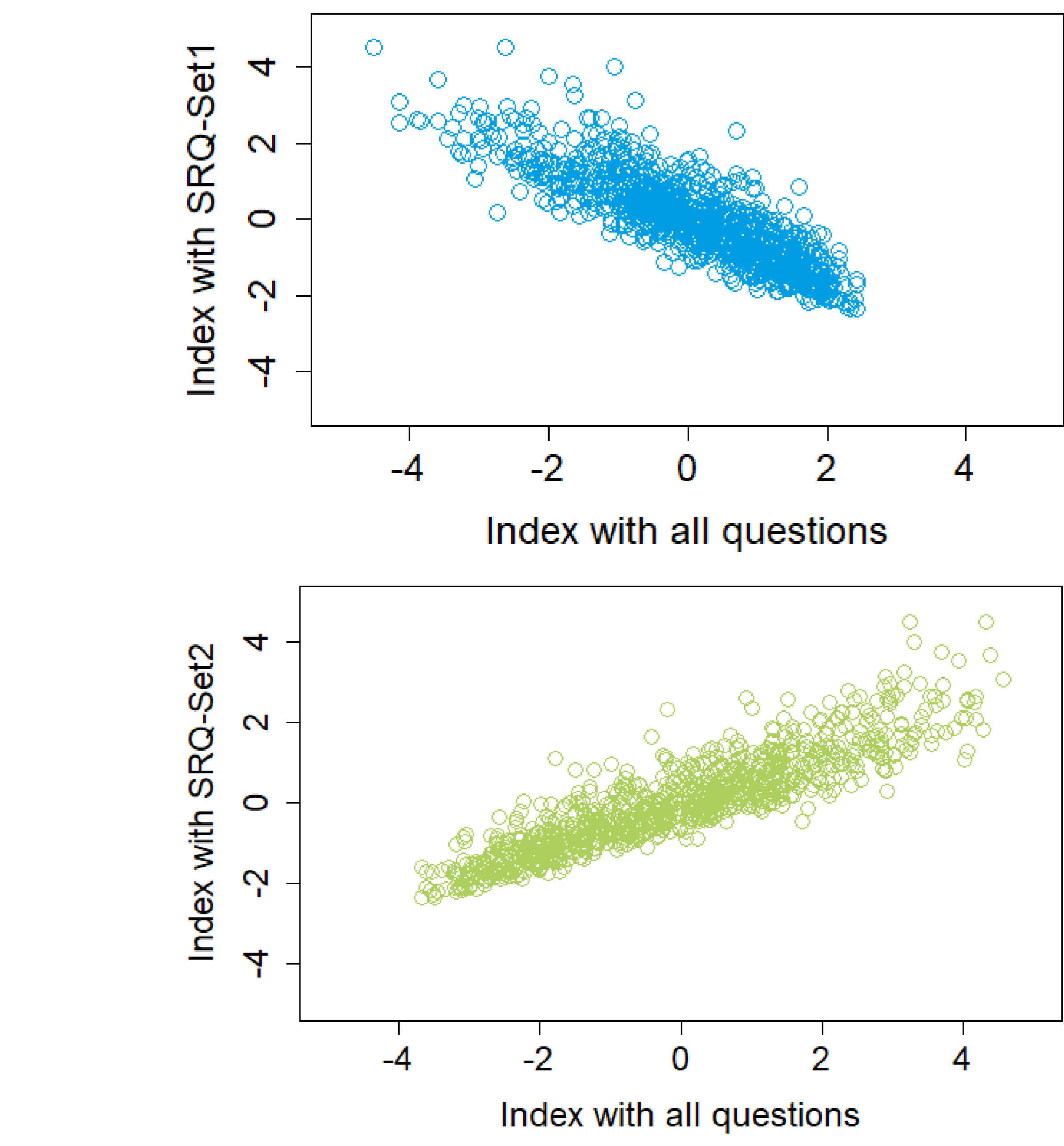
Conclusion

The results suggest that the composite single value speech-related benefit index using PCA can indicate the perceived benefit of hearing aid use.

The speech-related questions, the SRQ-set2, can be representative of overall benefit with a positive covariance to the index based on all questions included in the present study.

This approach can be extended using other powerful multivariate statistical tools like partial least square (PLS) method can open up more possibilities in predicting aided benefit using only audiometric and demographic variables.

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