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A new IRT-based standard setting method: Application to eCat-Listening

Pablo Eduardo García, Francisco José Abad, Julio Olea and David Aguado
Universidad Autónoma de Madrid

Abstract

Background: Criterion-referenced interpretations of tests are highly necessary, which usually involves the difficult task of establishing cut scores. Contrasting with other Item Response Theory (IRT)-based standard setting methods, a non-judgmental approach is proposed in this study, in which Item Characteristic Curve (ICC) transformations lead to the final cut scores. Method: eCat-Listening, a computerized adaptive test for the evaluation of English Listening, was administered to 1,576 participants, and the proposed standard setting method was applied to classify them into the performance standards of the Common European Framework of Reference for Languages (CEFR). Results: The results showed a classification closely related to relevant external measures of the English language domain, according to the CEFR. Conclusions: It is concluded that the proposed method is a practical and valid standard setting alternative for IRT-based tests interpretations.

Keywords: Standard setting, item response theory, computerized adaptive testing, criterion-referenced testing.

According to the Standards for Educational and Psychological Testing (American Educational Research Association [AERA], American Psychological Association [APA], & National Council of Measurement in Education [NCME], 1999), validity is the most essential matter to take into account when developing and evaluating tests. Organizations like the International Test Commission (ITC) or the European Federation of Psychologists’ Associations (EFPA) also emphasize the importance of validity, which refers to the degree to which evidence and theory support the interpretations of test scores required by the proposed uses of tests. As Cronbach and Meehl (1955) stated, one does not validate a test, but only a principle for making inferences.

Depending on the kind of interpretations to be made with tests scores, norm-referenced and criterion-referenced interpretations are usually differentiated. The former enables the interpretation of an examinee’s score compared to that of other examinees, whereas the latter allows users to interpret examinee test performance in relation to well-defined domains of content and/or behaviors. Thus, the primary purpose of criterion-referenced interpretations is not to determine the rank ordering of examinees, as is the case with norm-referenced interpretations, but rather to determine the placement of examinees in a set of ordered performance standards (Hambleton, 2003).

As Hambleton (2003) suggested, perhaps the most difficult steps for criterion-referenced interpretations are to set performance standards and to establish cut scores that finally allow separating examinees into such standards. According to Cizek and Bunch (2007), standard setting is the appropriate sequence of a prescribed, rational system of rules or procedures resulting in the assignment of cut scores to differentiate between two or more performance standards. This is why the AERA, APA and NCME (1999) stated that the validity of test interpretations sometimes hinges on the cut scores.

In this study, a new IRT-based standard setting method is proposed and applied to eCat-Listening in order to interpret its scores in relation to the Common European Framework of Reference for Languages.
eCat-Listening

eCat-Listening (Olea, Abad, Ponsoda, Barrada, & Aguado, 2011) is a computerized adaptive test for the evaluation of English Listening. Although, in its initial version, only norm-referenced interpretations were provided (estimation of trait-level and percentile ranks), it would be highly desirable to incorporate criterion-referenced interpretations. The test is usually applied in educational assessments and recruitment processes. In both cases, a criterion-referenced interpretation would provide information about the listening skills mastered by a person. For example, in a recruitment process, a norm-referenced interpretation might not be enough, because the highest scores do not guarantee the required skills.

eCat-Listening presents good psychometric properties (Olea et al., 2011): the bank is unidimensional, the items are satisfactorily fitted to the 3-parameter logistic model, and an accurate estimation of the trait level is obtained. A simulation study proved the adaptive administration to be efficient with a length of 20 items and a maximum exposure rate of 40.

Common European Framework of Reference for Languages (CEFR)

The Council of Europe published the Common European Framework of Reference for Languages (CEFR) in 2001, intended to provide objective criteria for describing language proficiency and thus facilitate the mutual recognition of qualifications gained in different contexts. It establishes six levels of language proficiency, labeled A1, A2, B1, B2, C1 and C2 (A: Basic User; B: Independent User; C: Proficient User). It includes a global scale and specifics for written/oral comprehension and written/oral production. The performance standards for oral comprehension are shown in Table 1.

In the last few years, many countries (inside and outside Europe) have accepted the CEFR, so they have had to relate their own exams to the Framework. The Council of Europe has made efforts to make this task easier and to guarantee rigorous procedures. The Council finally published a manual that includes several standard setting methods applied to the CEFR (Council of Europe, 2009).

Standard setting methods

According to North and Jones (2009), it is useful to classify standard setting methods into two groups: those that make use of the Item Response Theory (IRT) and those that do not. The latter can also be classified into examinee-centered methods (i.e., Contrasting Groups, Borderline Group, Body of Work) and test-centered methods (i.e., Tucker-Angoff, Nedelsky, Basket).

Concerning IRT-based methods, their principal advantage is that they allow the cut scores to be determined once on the item bank scale, rather than repeatedly for each new form of the test. This is due to the useful parameter invariance property of IRT.

Two IRT-based methods that have become popular in the last few years are the Bookmark Method (Mitzel, Lewis, Patz, & Green, 2001) and the Item-Descriptor Matching Method (Ferrara, Perie, & Johnson, 2002).

In the Bookmark Method, for every performance standard, the experts must decide, for each item, whether a person who reaches that standard masters the item or not. Mastery is defined in probabilistic terms, so the person that masters an item will give the correct response with a rather high probability. The exact definition of “rather high probability”, denoted as Response Probability (RP), is in principle arbitrary, but it should involve a profound reflection about mastery and about the implications of classifying examinees in different performance standards. The Bookmark authors employ a RP of .67, although they recognize that alternative values, as .50 or .80, could be employed as well (Mitzel et al., 2001). In the Item-Descriptor Matching Method, experts must decide to which performance standard the knowledge, skills, and cognitive processes required to respond successfully to an item are most closely matched. In both IRT-based methods, items are first calibrated and then presented to the experts in order of difficulty, which facilitates their task. In spite of this operative advantage, the success of these methods seems to depend quite critically on the close relation between item difficulty and the performance standards to which they belong. “Ideally, one would say that an item that only requires abilities and skills described at A2 is easier than an item developed for B1. This, however, might be too simplistic a view for a sound theory on item difficulty” (Council of Europe, 2009, p. 75).

Proposed method

Contrasting with the IRT-based preceding methods, the one proposed here does not require the judgment of experts to set the cut scores. The method reaches the final cut scores by performing

<table>
<thead>
<tr>
<th>Label</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Can follow speech which is very slow and carefully articulated, with long pauses for him/her to assimilate meaning</td>
</tr>
<tr>
<td>A2</td>
<td>Can understand phrases and expressions related to areas of most immediate priority (e.g. very basic personal and family information, shopping, local geography, employment) provided speech is clearly and slowly articulated</td>
</tr>
<tr>
<td>B1</td>
<td>Can understand the main points of clear standard speech on familiar matters regularly encountered in work, school, leisure etc., including short narratives</td>
</tr>
<tr>
<td>B2</td>
<td>Can understand the main ideas of propositionally and linguistically complex speech on both concrete and abstract topics delivered in a standard dialect, including technical discussions in his/her field of specialization</td>
</tr>
<tr>
<td>C1</td>
<td>Can follow extended speech and complex lines of argument provided the topic is reasonably familiar, and the direction of the talk is sign-posted by explicit markers</td>
</tr>
<tr>
<td>C2</td>
<td>Has no difficulty in understanding any kind of spoken language, whether live or broadcast, delivered at fast native speed</td>
</tr>
</tbody>
</table>
ICC transformations that summarize item families’ responses. To classify one person in a performance standard, the method considers not only the probability of a correct response to the items of such standard, but also of the less demanding standards. The method involves the following steps:

1. Criterion-based item bank construction:

A panel of experts constructs the item bank. According to the abilities and skills each item requires, they generate \( k \) item families corresponding to \( k \) well-defined performance standards by which test scores might be interpreted and examinees classified. The bank must represent all the standards well, so the families must be composed of a similar number of items.

For eCat-Listening, six item families must be developed corresponding to each CEFR performance standard. These families are denoted here as \( kA1 \), \( kA2 \), \( kB1 \), \( kB2 \), \( kC1 \) and \( kC2 \).

2. Item bank calibration - ICC estimations:

All items are calibrated, and ICCs estimated. In IRT, the ICC represents the probability of a correct response to the item as a function of a person trait, denoted by \( \theta \). According to the 3-parameter logistic model (normal metric), for item \( j \), this is:

\[
P_j(\theta) = \frac{1}{1 + e^{-a_j(\theta-b_j)}}
\]

The meanings of the parameters are:
- \( a \) pseudo-guessing parameter: it represents the probability of a correct response for people whose trait level is extremely low.
- \( b \) difficulty parameter: it indicates the ICC location in the abscissa axis (the more difficult the item is, the more to the right is the ICC), \( \theta \) and \( b_j \) are in the same metric. For \( P_j(\theta) \) we have:

\[
\theta = b_j, \quad P_j(\theta) = \frac{1}{2} + c_j
\]

- \( c \) discrimination parameter: it is directly related to the ICC slope in \( \theta = b_j \).

3. Averaged-ICC calculation for every item family:

The averaged-ICC for an item family represents the averaged probability of a correct response to an item classified in that family as a function of \( \theta \). For a family \( k \) made up of \( J \) items, it is denoted by \( AP_k \) and obtained by calculating (for each \( \theta \) value) the arithmetic mean of \( P_j(\theta) \):

\[
AP_k(\theta) = \frac{\sum_{j=1}^J P_j(\theta)}{J}
\]

Thus, for each item family \( k \), \( AP_k \) may be interpreted as the ICC of the prototypical item of that family. For example, \( AP_{kA2} \) indicates the probability of a correct response to the prototypical item of \( kA2 \) as a function of \( \theta \). There are six \( AP_k \) to be calculated with eCat-Listening.

4. Joint averaged-ICC calculation for every item family:

The Joint Averaged-ICC for an item family (e.g., \( kB1 \)) represents the joint probability (as a function of \( \theta \)) of a correct response to the prototypical item of that family (the individual probability of which is represented by \( AP_k \)) and to the prototypical items of each one of the less demanding item families (\( kA2 \) and \( kA1 \), in this case).

For a \( k \) family, it is represented as \( JAP_k \). Based on the local independence property of IRT, it is obtained multiplying (for each \( \theta \) value) the averaged-ICCs (\( AP_k \)’s) of the item families involved:

\[
JAP_k(\theta) = \prod_{k=1}^{6} AP_k(\theta)
\]

There are six \( JAP_k \) to be calculated with eCat-Listening. They are used to obtain the cut scores.

5. Choosing the cut scores by determining the Response Probability (RP). Validity analyses with external criteria:

Given the Joint Averaged-ICC for one item family (\( JAP_k \)), the expected probability for a person who has just barely achieved the corresponding performance standard (i.e., borderline person) must be decided. That expected probability is denoted by \( RP_k \), in a similar way this term is used in standard setting literature.

Once the \( RP \) has been decided, the cut score for each performance standard (denoted by \( \theta_{j'} \)) is that which leads to that probability in the corresponding \( JAP_{k'} \), so:

\[
JAP_{k'}(\theta_{j'}) = RP_k
\]

Cut scores for eCat-Listening are \( \theta_{A0}, \theta_{A1}, \theta_{A2}, \theta_{B0}, \theta_{B1}, \theta_{B2}, \theta_{C1}, \theta_{C2} \). They lead to an ordinal variable named Assigned Standard, with seven levels, called: \( A0' \)—for people who do not reach \( \theta_{A0} = A1' \), \( A2' \), \( B1' \), \( B2' \), and \( C1' \), \( C2' \) (see Table 2).

Although there is no strict rationale to choose a particular value for \( RP \), the choice one makes has definite consequences on the standards that will be found. There would be infinite cut score solutions for infinite possible \( RP \) possible values.

Here, we propose, firstly, to obtain three cut score solutions corresponding to the \( RP \) values of .50, .67 and .80, and then, to compare and validate each solution through external criteria measures. As stated by North and Jones (2009), it is very important
for external criteria to be integrated into the standard setting procedure, because “the more that it can be integrated into the project, the greater the chances of an effective outcome” (p. 18). According to Hambleton (2003), validity assessment might focus on the relationship between classifications made on the basis of the standard setting conducted and classifications or on performance ratings provided externally to the test (e.g., teacher ratings or job performance ratings).

Method

Participants

Two experts in English philology, with the collaboration of three experts in psychometrics, developed and classified an initial item bank for eCat-Listening (227 items), according to the CEFR performance standards for listening comprehension.

One hundred and two items were administered to a sample of 1,576 people, mainly participants in selection processes. Six hundred and thirty-five of them were students from the Escuela Oficial de Idiomas (EOI; Official School of Languages).

Instruments

eCat-Listening. Three subtests were elaborated, each one with 42 items: 12 as the anchor test and 30 specific items. Subtests were elaborated to properly represent the six CEFR performance standards. The total sample of 1,576 people was divided into three subsamples (n1 = 592, n2 = 605, n3 = 379 for each subtest).

Criteria measures. In order to perform validity analyses, eCat-Grammar (Olea, Abad, Ponsoda, & Ximénez, 2004), which is a computerized adaptive test for the assessment of written English, and a self-report questionnaire about English knowledge and studies were administered. In the questionnaire, the participants informed about: (a) the type of school where they had attended their middle studies (bilingual-English or others), (b) their perceived mastery in English (Reading, Writing and Oral_perceived_mastery), and (c) their training in English (primary and secondary education, academies —Years_in_academy—, family, stays in Anglo-Saxon countries, and others). Lastly, the EOI students informed about the grade they were registered in at that school (EOI_grade: “Básico” 1, “Básico” 2, “Intermedio” 1, “Intermedio” 2, “Avanzado” 1, “Avanzado” 2) and their educational level (Educational_level: no studies, primary studies, secondary studies, university studies).

Data analysis

ICCs were estimated with the Bayesian marginal maximum-likelihood procedure, because “the more that it can be integrated into the project, the greater the chances of an effective outcome” (p. 18). According to Hambleton (2003), validity assessment might focus on the relationship between classifications made on the basis of the standard setting conducted and classifications or on performance ratings provided externally to the test (e.g., teacher ratings or job performance ratings).

Firstly, stepwise multiple linear regression was performed in order to determine which variables were significant predictors of θ before being discretized.

Secondly, significant predictors from the linear regression were included as predictors of Assigned Standard in an ordinal regression. Pseudo-$R^2$ statistics were calculated in order to assess and compare the intensity of the relation between predictors and each Assigned Standard variable.

Lastly, contingency tables were obtained to analyze the relationship between each Assigned Standard and the variables Oral_perceived_mastery and EOI_grade, the two variables with the highest standardized coefficients in the linear regression, after eCat-Grammar, and which provide correct English mastery classifications. The EOI_grade is actually a very useful variable because the EOI relates its grades to the CEFR performance standards. Due to nonsignificant differences in θ between adjacent grades (Olea et al., 2011), the original EOI grades “Básico” 1 and 2, “Intermedio” 1 and 2, and “Avanzado” 1 and 2 were grouped, respectively, into Basic, Intermediate and Advanced. According to the EOI equivalences between its grades and the CEFR performance standards (EOI, 2011), those mainly expected standards achieved by students in each grade are: A0’, A1’ and A2’, in Basic; A2’ and B1’, in Intermediate; B1’ and B2’, in Advanced. Contingency tables were interpreted according to these expected values.

Results

Joint averaged-ICC calculation

ICCs were estimated for the definitive bank of 95 items (specific criteria for selecting items can be consulted in Olea et al., 2011). Averaged-ICCs (APk)s obtained for each family k are shown in Figure 1.

As shown in Figure 1, kA1 and kA2 curves overlap, as do curves kB2 and kC1. This is probably due to disordinality, which refers to the fact that a panelist may have a different perception of item difficulty or demand than is indicated by its empirical characteristics (Pant, Rupp, Tuffin-Richards, & Köller, 2009).

Figure 1. Averaged-ICCs for the six item families

- kA1
- kA2
- kB1
- kB2
- kC1
- kC2

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The coefficients for the resulting five significant predictors from criteria variables.

Validity analyses with external criteria

In the multiple linear regression of \( \theta \) on criteria measures, the ANOVA was statistically significant \( (F_{5,629} = 194.74, p<0.0005) \). The coefficient of determination \( R^2 \) was 0.61. Table 4 shows the regression coefficients for the resulting five significant predictors from criteria variables.

The significant predictors shown in Table 4 were those used for ordinal regression. McFadden statistics corresponding to DVs Assigned Standard_50 and Assigned Standard_67 were very similar (0.272 and 0.277, respectively) and, therefore, inconclusive for selecting the cut score solution.

Tables 5 and 6 present the contingency tables Oral perceived mastery \( \times \) Assigned Standard_50 and Oral perceived mastery \( \times \) Assigned Standard_67.

Many of the values from Table 5 were expected. Almost 70% of the people who said they spoke/understood English as well as Spanish were classified as C2’ or C1’. Most of the people who said they could not speak English were classified as A0’ or A1’. Most of people who said they could speak/understand English well were classified as B2’ or higher, etc.

However, the results shown in Table 6 were unexpected. Half of the people who said they spoke/understood English as well as Spanish were classified as B1’ or lower. More than 70% of the people who said they could speak/understand English with difficulty in diverse social contexts were classified lower than B1’, etc.

Table 7 and 8 present the contingency tables EOI grade \( \times \) Assigned Standard_50 and EOI grade \( \times \) Assigned Standard_67.

Most of the values from Table 7 were expected. More than 90% of the Basic students were classified as A0’, A1’ or A2’. Nearly 70% of Intermediate students were classified as A2’ or B1’. And more than 60% of Advanced students were classified as B1’ or B2’.

On the other hand, the values from Table 8 were unexpected. The majority of the Intermediate students were classified as A0’ or A1’. And half of the Advanced students were classified as A2’ or lower.

In conclusion, individual analyses allowed choosing the cut scores corresponding to \( RP = .50 \) (see Table 3) as the best solution of those contrasted.

Discussion

In order to guarantee the validity of psychological and educational testing, criterion-referenced interpretations of scores are necessary. Nevertheless, as Elosua (2012) has shown, most of the manuals of widely used tests still propose only normative interpretations.

Fortunately, criterion-referenced testing is becoming widespread in some fields. That is the case with language-proficiency assessments, where it is especially relevant to determine what examinees know or can do in relation to well-defined performance standards, like those provided by the CEFR, rather than in relation to other persons. Actually, the CEFR has increasing influence on language testing organizations and stakeholders worldwide that

\[
\begin{array}{ccccccc}
\text{Table 3} \\
\text{Cut Scores for RPs of .50, .67 and .80} \\
\hline
\text{Cut score} & \theta_{A1} & \theta_{A2} & \theta_{B1} & \theta_{B2} & \theta_{C1} & \theta_{C2} \\
\text{.50} & -1.93 & -1.0 & -0.1 & 0.81 & 1.12 \\
\text{.67} & -1.03 & -0.22 & 0.39 & 0.94 & 1.22 & 1.52 \\
\text{.80} & -0.33 & 0.35 & 0.92 & 1.40 & 1.65 & 1.96 \\
\hline
\end{array}
\]

Note: AP value for each standard cut score is shown in brackets. As logical, it is equal to \( RP \) in \( \theta_{A1} \).
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seek to align their exams to that Frame for reasons of transparency and coherence (Taylor & Jones, 2006). According to Tannenbaum and Wylie (2008), by relating test scores to the CEFR, an operational bridge is built between psychometrically sound, standardized assessments of language competencies and meaningful CEFR-based classifications of such competencies. Prestigious English-language test providers like Cambridge or Educational Testing Service (ETS) actually try to align their exams to the Frame. Relating a language-proficiency test to the CEFR involves establishing cut scores that allow classifying examinees according to the Frame. There are many standard setting methods to establish cut scores, and there is no agreement in the field about which is the best one, which probably depends on the features and objectives of the testing involved. In any event, regardless of which method is chosen, it must be based on non-arbitrary, explicit, and clearly documented criteria (AERA, APA, & NCME, 1999; Cizek & Bunch, 2007). Furthermore, some external criteria might be integrated into the procedure with the aim of validating the interpretations and classifications that the cut scores lead to.

The current study has proposed a new IRT-based standard setting procedure that, compared to other available methods, does not require experts judgments to obtain the final cut scores. The method involves working with ICC transformations to obtain possible cut score solutions and performing validity analyses to compare them and choose the best one. In the case of eCat-Listening, cognitive cut scores led to an ordinal variable that was significantly and highly related to external measures of the English-language domain, according to the CEFR.

In spite of this successful application to eCat-Listening, it is important to realize that item bank development is critical for this method. So the better the test developers classify the items into the performance standards, the better the method works. A highly difficult task that, contrasted with other IRT-based methods, cannot be facilitated by item difficulty information or feedback.

Some reflection about the way the method summarizes item family ICCs should be made also. In spite of the successful application of the method to eCat-Listening, by obtaining the

Table 5
Contingency table: Oral_perceived_mastery × Assigned_Standard_50

<table>
<thead>
<tr>
<th>Description</th>
<th>Assigned_Standard_50</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A0'</td>
</tr>
<tr>
<td>Cannot speak/understand English</td>
<td>33.3%</td>
</tr>
<tr>
<td>Only easy conversations</td>
<td>4%</td>
</tr>
<tr>
<td>In several contexts, but with difficulty</td>
<td>1.5%</td>
</tr>
<tr>
<td>Well</td>
<td>0%</td>
</tr>
<tr>
<td>As well as Spanish</td>
<td>0%</td>
</tr>
</tbody>
</table>

Note: Percentages by row. They are in boldface if corrected standardized residuals are greater than +1.96.

Table 6
Contingency table: Oral_perceived_mastery × Assigned_Standard_67

<table>
<thead>
<tr>
<th>Description</th>
<th>Assigned_Standard_67</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A0'</td>
</tr>
<tr>
<td>Cannot speak/understand English</td>
<td>62.5%</td>
</tr>
<tr>
<td>Only easy conversations</td>
<td>31.3%</td>
</tr>
<tr>
<td>In several contexts, but with difficulty</td>
<td>8.3%</td>
</tr>
<tr>
<td>Well</td>
<td>8%</td>
</tr>
<tr>
<td>As well as Spanish</td>
<td>0%</td>
</tr>
</tbody>
</table>

Note: Percentages by row. They are in boldface if corrected standardized residuals are greater than +1.96.

Table 7
Contingency table: EOI_grade × Assigned_Standard_50

<table>
<thead>
<tr>
<th>Grade</th>
<th>Assigned_Standard_50</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A0'</td>
</tr>
<tr>
<td>Basic</td>
<td>6%</td>
</tr>
<tr>
<td>Intermediate</td>
<td>0%</td>
</tr>
<tr>
<td>Advanced</td>
<td>0%</td>
</tr>
</tbody>
</table>

Note: Percentages by row. They are in boldface if corrected standardized residuals are greater than +1.96.

Table 8
Contingency table: EOI_grade × Assigned_Standard_67

<table>
<thead>
<tr>
<th>Grade</th>
<th>Assigned_Standard_67</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A0'</td>
</tr>
<tr>
<td>Basic</td>
<td>33.9%</td>
</tr>
<tr>
<td>Intermediate</td>
<td>13%</td>
</tr>
<tr>
<td>Advanced</td>
<td>1.1%</td>
</tr>
</tbody>
</table>

Note: Percentages by row. They are in boldface if corrected standardized residuals are greater than +1.96.
arithmetic mean of individual probabilities some of the averaged curves were overlapping. Although it was thought to be explained by the phenomenon known as disordinality, it would be interesting to contrast other existing procedures to summarize data from item families. For instance, Sinharay, Johnson, and Williamson (2003) introduced the concept of family expected response function (FERF), which summarizes ICCs via a Bayesian hierarchical model. Further investigation is suggested to analyze the advantages and disadvantages of incorporating this or other procedures into the standard setting method proposed here.

Acknowledgements

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References


