

Psychometric Evaluation of a Receptive Vocabulary Test for Greek Elementary Students

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Abstract

Assessment of lexical/semantic knowledge is performed with a variety of tests varying in response requirements. The present study exemplifies the application of modern statistical approaches in the adaptation and assessment of the psychometric properties of the *Peabody Picture Vocabulary Test–Revised* (PPVT-R) Greek. Confirmatory factor analyses applied to data from a large sample of elementary school students ($N = 585$) indicated the existence of a single vocabulary dimension and differential item functioning procedures pointed to minimal bias due to gender or ethnic group. Rasch model–derived indices of item difficulty and discrimination were used to develop a short form of the test, which was administered to a second sample of 900 students. Convergent and discriminant validity were assessed through comparisons with the *Wechsler Intelligence Scales for Children–III* Vocabulary and Block design subtests. Short- and long-term stability of individual scores over a 6-month period were very high, and the utility of the test as part of routine educational assessment is attested by its strong longitudinal predictive value with reading comprehension measures. It is concluded that the Greek version of the PPVT-R constitutes a reliable and valid assessment of vocabulary for Greek students and immigrants who speak Greek.

Keywords

language tests, PPVT, Rasch model, item difficulty

The *Peabody Picture Vocabulary Test–Revised* (PPVT-R) was introduced by L. M. Dunn and Dunn (1981) as a measure of receptive vocabulary for children. Since its introduction, it has been widely used in research and practice (e.g., Pankratz, Morrison, & Plante, 2004). The examinee is asked to indicate on a stimulus plate which of four drawings corresponds to a spoken word (noun, verb, or adjective). Because of the special response requirements of the tasks, it is reasonable to expect that perceptual organization and decision-making ability may account for a certain amount of individual variability in performance, although, at least in children, PPVT-R performance loads primarily on verbal comprehension-related factors (Culbert, Hamer, & Klinge, 1989; D’Amato, Gray, & Dean, 1988). The utility of the test has been appraised for a variety of clinical groups and purposes. Ease of administration and scoring and the fact that the test does not require a verbal response make it appealing for assessing language as well as general intellectual ability in children with intellectual disabilities, severe language impairments, or emotional and behavioral disorders (Ollendick, Finch, & Ginn, 1974; Parnak, Willson-Quayle, & Whitten, 1998).

The PPVT-R has often been used as a measure of lexical (i.e., word) knowledge in studies investigating sources of

individual variability in reading achievement (for a recent review see Joshi, 2005). In addition to the theoretical expectation that strong vocabulary knowledge would facilitate fluency and reading comprehension (Dixon, LeFevre, & Twilley, 1988; Frost, Madsbjerg, Niedersoe, Olofsson, & Sorensen, 2005), several recent empirical findings appear to support this thesis (Vellutino, Tunmer, Jaccard, & Chen, 2007; Verhoeven, van Leeuwe, & Vermeer, 2011; Yovanoff, Duesbery, Alonzo, & Tindal, 2005). Furthermore, some authors argued that the benefits from an extensive oral language vocabulary extend far beyond reading comprehension to promote future academic success (Beck & McKeown, 1991; Biemiller, 1999). In recent studies, measures of lexical/semantic knowledge including PPVT-R were found to account for significant amounts of variance in reading comprehension scores even after controlling for age, word/nonword reading skills, automatized naming, and listening

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comprehension or nonverbal intelligence, in elementary education students (Protopapas, Sideridis, Mouzaki, & Simos, 2007) and young adults (Braze, Tabor, Shankweiler, & Mencl, 2007). Word knowledge may account for discrepancies between decoding and reading comprehension skills (Oakhill, Cain, & Bryant, 2003). While vocabulary measures cannot substitute print-based comprehension measures in the assessment of text-related reading difficulties, they may provide useful information regarding individual weaknesses in lexical knowledge, which could then be targeted as part of comprehensive remediation programs. Recently, there has been an increasing evidence-based trend to develop reading interventions using a flexible group approach based on patterns of linguistic and cognitive strengths and weaknesses of individual students (Denton & Vaughn, 2010; Elbaum, Vaughn, Hughes, & Moody, 2000; Vaughn & Linan-Thompson, 2003).

In this context, it is necessary to identify valid indices of both the depth and breadth of lexical knowledge (Ouellette, 2006), which, according to one view, should reflect the existence of lexical entries associated with redundant (phonological, orthographic, and semantic) information (Perfetti, 2007; Perfetti & Hart, 2001). Notably, vocabulary measures subsume most comprehension variance at a comparatively higher psychometric reliability and greater ease of test construction, administration, and scoring (Protopapas, Mouzaki, Sideridis, Kotsolakou, & Simos, *in press*; Protopapas, Simos, Sideridis, & Mouzaki, *in press*). Vocabulary measures such as the PPVT are thus important in the assessment of clinically and academically relevant verbal skills in a wide age range. The present study evaluated the psychometric properties of the Greek adaptation of the PPVT-R (reliability, concurrent and predictive validity, internal structure, and item bias) addressing the need of sensitive measures of lexical knowledge for psychologists, speech therapists, and special educators. A short version of the test was derived through Rasch model-based item-level analyses offering professionals greater flexibility in the design of comprehensive, yet relatively brief, assessment batteries for specific weaknesses that can become targets of effective educational interventions.

Importance of the Study

In view of the demonstrated utility and predictive value of the PPVT-R for both clinical and research purposes, a detailed investigation of its psychometric adequacy is desirable. This is particularly important given the fact that the validity of the PPVT-R has been questioned on the grounds that it is influenced by motivational factors (Zigler, Abelson, & Seitz, 1973), characteristics of the examiners (Lasky, Felice, Moyer, Buddington, & Elliot, 1973), or students' placement (Seitz, Abelson, Levine, & Zigler, 1975). In light of the above concerns, it is important to examine the validity of the PPVT-R for a range of populations and assessment purposes. Despite reported gender and

ethnic differences in PPVT total scores (Qi, Kaiser, Milan, & Hancock, 2006; Wolf & Gow, 1985/1986), bias at the item level remains understudied. So far, very few studies have tested for item bias across populations (Colarusso, McLeskey, & Gill, 1977; Jensen, 1974), none of which have employed the Rasch model, which is arguably most appropriate for the detection of such biases affording non-linear modeling and control for ability levels.

In addition to possible bias, instrument dimensionality and stability are also important. Unidimensionality of the PPVT has traditionally been assessed using standard factor-analytic techniques, instead of the more appropriate procedures that accommodate dichotomous data (*i.e.*, based on polychoric correlations; Ball, Payne, & Hallahan, 1973; D'Amato et al., 1988). Only recently have such analytical advances been implemented in statistical software (*e.g.*, EQS; Bentler, 2000). So far, the items of the PPVT have not been calibrated across grades and tested over time. The stability of the normative distribution of scores must be assessed if the measure is to be used as a longitudinal predictor of disability or achievement; however, there are few data bearing on this issue (*e.g.*, Naglieri & Pfeiffer, 1983; Scruggs, Mastropieri, & Argulewicz, 1983). Finally, and in conjunction with potential biases, the invariance of the one-factor model to explain data from various populations has not been established. This would entail tests of measurement invariance across populations, such as those represented by different age groups or grades (for a description see G. Dunn, Everitt, & Pickles, 2002).

The present study complements and extends previous studies by examining specific psychometric attributes of the PPVT-R through Rasch and Confirmatory Factor Analysis (CFA) models, to address the aforementioned concerns. As such, it provides added support for the utility of PPVT-R in educational contexts. The investigation of dimensional stability and gender and ethnic (immigrant status) bias is particularly important in this respect as it ensures a solid psychometric foundation for the professional using PPVT-R with diverse student populations. The type of data used in the present study (including additional standardized measures of vocabulary, nonverbal intelligence and reading achievement, obtained both concurrently and longitudinally) and the analysis procedures may also serve as a model for similar validation studies in other languages. Finally, the study addresses the need for a brief measure of receptive vocabulary for school-aged children in Greek that can be used for both clinical and research purposes.

Method

Participants

Pilot study. Pilot data on the entire translated version of PPVT-R Form L were collected from two groups. The first group included 50 children 6 to 7 years old, attending

Table 1. Demographic Information for Cohort 1

Variable	Age Range (Months)						
	87–95	96–104	105–113	114–123	124–131	132–139	140–147
Mean (SD) age (in months)	92 (2.4)	100 (2.6)	109 (2.5)	118 (2.8)	128 (2.2)	135 (2.3)	143 (2.1)
<i>n</i>	130	126	124	139	117	107	108
Grade	G2	54 (G2) 71 (G3)	96 (G3) 27 (G4)	G4	G5	49 (G5) 58 (G6)	G6
Gender (boys/girls)	63/67	59/67	59/65	68/71	50/67	55/52	52/56
Occupation (father, % Levels A/B/C/E ^a)	11/51/20/18	14/50/22/14	12/50/24/14	9/41/28/22	9/47/28/16	11/50/21/18	10/40/30/20
Occupation (mother, % Levels A/B/C/D/E ^a)	12/48/11/26/3	14/48/7/27/4	16/45/16/20/3	10/47/13/27/3	12/48/12/26/2	14/44/19/19/4	11/46/12/27/4
IQ ^b	9.5 (2.3)	9.6 (2.4)	9.8 (2.4)	9.5 (2.4)	9.7 (2.4)	9.9 (2.5)	9.5 (2.3)

a. Level A: professionals in disciplines that require higher education degree; Level B: mainly clerical workers whose position did not require higher education degree; Level C: primarily small private (including family) business owners; Level D: homemakers (mothers only); and Level E: laborers, farmers, and unemployed persons.

b. Mean standard score of *Wechsler Intelligence Scale for Children* (WISC)–III Vocabulary and Block Design.

regular classrooms, without a history of learning difficulties (based on the school records and teacher report) in four public schools in Athens and rural Rethymno, Crete, aiming primarily to assess the appropriateness of the first 49 items of the test. Selection of classrooms and students within each school followed a stratified randomized procedure. Given that the test is also intended for use with adults, a second group of 70 young adults (age range 18–38 years; 35 men) was tested, including college students and residents of Athens and Rethymno (a town with a population of approximately 20,000, on the island of Crete). This sample included an intentional overrepresentation (55%) of persons with 9 years of formal education or fewer. Adult participants were recruited through ads posted in the university and in local companies. Quantitative as well as qualitative data from the adult participants were used to identify plates that might be culturally inappropriate or require modifications in the corresponding target words.

Cohort 1. The adapted version of the PPVT-R (based on the pilot data) was administered to 585 students attending Grades 2 to 4 in Crete, Athens, and the island of Zakynthos (Time 1; see Table 1). School selection followed a stratified randomized approach in an effort to include units representative of urban (seven schools), rural (three schools), and semi-urban areas (seven schools). Children were selected randomly from each class but only those whose parents gave written permission for participating in the research were included in the study. There were 537 Greek students and 48 of Albanian origin (immigrants) who had attended Greek schools since Grade 1 and had adequate language skills (i.e., comparable to typical Greek students based on teacher report). A subset of 500 students were retested 6 months later in order to estimate the long-term stability of PPVT-R scores (Time 2). Finally, 24 months after the initial assessment (Time 3), a measure of

reading comprehension (Test of Reading Performance; Sideridis & Padeliadu, 2000) was also available for 494 of these students, in addition to PPVT-R scores, in order to establish the predictive validity of the test.

The sample described in Table 1 includes students without history of learning disability (based on school records and teacher report), attending regular public school classrooms. All students were administered the WISC-III Vocabulary and Block Design subtests (in order to screen for potential undiagnosed intellectual disability) achieving standard scores > 4 and Greek as their primary language. Parental occupation of participants was classified into five major occupational levels intended to reflect in part the educational level of the parent as well. Level A included professionals in disciplines that require higher education degree, including teachers (corresponds roughly to Level I used by L. Dunn et al., 1986); Level B included mainly clerical workers whose position did not require higher education degree (corresponds roughly to Levels II and IV in L. Dunn et al., 1986); Level C included primarily small private (including family) business owners; Level D included homemakers (in our samples it applies to mothers only); and Level E included laborers, farmers, and unemployed persons (Levels III and IV in L. Dunn et al., 1986).

Cohort 2. The Short version of the PPVT-R, developed using procedures described in more detail below, was administered to a separate sample of 916 children in Grades 1 to 6. This sample was obtained from four broad geographical regions of Greece (Thessaloniki, Thessaly, Attiki, and Crete) and was representative of the Greek student population in terms of type of geographical region and parent education level. Detailed demographic information is presented in Table 2. All students had Greek as their primary language, no history of learning disability (based on teacher report),

Table 2. Demographic Information for Cohort 2

Variable	Age Range (Months)						
	75–82	83–90	91–98	99–107	108–116	117–125	126–134
Mean (SD) age (in months)	79 (2.2)	87 (2.3)	94 (2.1)	103 (2.5)	112 (2.6)	121 (2.6)	130 (2.3)
<i>n</i>	130	129	114	150	150	118	132
Grade	G1	G1 (60) G2 (69)	G2	G3	G3 (40) G4 (110)	G4 (70) G5 (48)	G5 (68) G6 (62)
Gender (boys/girls)	64/66	65/64	58/56	80/70	63/87	64/54	69/63
Occupation (father, % Levels A/B/C/E ^a)	16/46/8/25	14/39/16/31	15/40/9/37	11/42/10/41	16/41/13/30	21/34/12/33	18/32/15/34
Occupation (mother, % Levels A/B/C/D/E ^a)	20/36/6/30/8	17/18/5/50/10	22/33/-/35/10	13/30/7/38/12	22/24/3/43/8	26/35/2/27/10	22/34/4/34/6
IQ ^b	.05 (.66)	-.05 (.64)	.03 (.73)	.007 (.70)	.02 (.72)	.03 (.67)	.08 (.74)

a. Level A: professionals in disciplines that require higher education degree; Level B: mainly clerical workers whose position did not require higher education degree; Level C: primarily small private (including family) business owners; Level D: homemakers (mothers only); and Level E: laborers, farmers, and unemployed persons.

b. Mean standard score of *Wechsler Intelligence Scale for Children (WISC)–III* Vocabulary and Block Design. Estimated IQ (z score) based on *WISC–III* Vocabulary and Raven Progressive Matrices Short Forms

attended regular public school classrooms, and scored in the average or above average range (no less than 2 SDs below the population mean) on an IQ index composed of standard (z) scores on *Wechsler Intelligence Scales for Children (WISC)–III* Vocabulary and Raven Progressive Matrices Short Forms. Parental occupation was classified as for Cohort 1.

Measures

Word reading accuracy was measured with the *Test of Reading Performance (TORP; Sideridis & Padeliadu, 2000)*–subscale 5, which is a list of 40 printed words to be read aloud without time pressure. Pseudoword reading accuracy was measured with TORP–subscale 6, which is a list of 19 printed pseudowords to be read aloud without time pressure. Reading comprehension was measured with TORP–subscale 13, which includes six passages of increasing length and two to four multiple-choice questions after each passage. Expressive vocabulary was tested with the vocabulary subtest of the Greek standardization of *WISC–III* (Georgas, Paraskevopoulos, Bezevegis, & Giannitsas, 1997), in which children provide word definitions. Nonverbal intelligence was tested with the Block Design subtest of the *WISC–III*, in which children re-create geometric designs using two-colored blocks. Details of the assessment measures are reported in Sideridis, Mouzaki, Simos, and Protopapas (2006) and Protopapas et al. (2007); see Protopapas, Simos et al. (in press) for measure reliability information. All measures were administered at Time 1 and all but *WISC–III* Block Design at Time 3. Only the PPVT-R was administered at Time 2.

Procedures

All children were tested individually by a group of Psychology graduates with prior experience in the administration of psychometric tests, who underwent an additional 1-week custom training program. Training included supervised administration of the test battery to the study coordinators and to at least two students (not included in the final sample) under supervision by the study coordinators with rigorous pass–fail criteria monitored on a structured checklist. Research assistants who committed more than three administration errors in three mock testing sessions were excluded from the research group. Students who made one to three errors were given additional training and repeated the mock assessments until they demonstrated flawless administration.

Participation in the project was voluntary and participants were aware that they could decline to respond to any item or that they could terminate their involvement at any time. Short breaks were taken as required. Participant responses were recorded manually and entered into an SPSS database by a separate group of research assistants. Spot-checks for data entry accuracy were performed on 5% of the cases and error rates at the item level were estimated to be less than 1%. Cases with any missing item-level data for PPVT-R full and short forms were not included in further analyses (five cases that were excluded from Cohort 1 and nine cases from Cohort 2 are not included in the samples reported here).

Based on the pilot data, extensive modifications were deemed necessary in the structure of the test in order to

accommodate linguistic and cultural differences. Pilot data from children aged 6 to 7 years indicated that the first 49 items in the original version were very easy for this age range (correct response rate was >85% for all items). Accordingly, administration of the test to Cohort 1 children started with Item 50 (the starting point for children aged 6.5 years in the English version of PPVT-R). Pilot data from the adult group indicated that two of the original plates (Items 65 and 69) contained culturally unfamiliar stimuli and were excluded from the Greek adaptation, leaving a total of 173 plates. For 44 of the stimulus plates, the Greek translation of the original target word was judged to be ambiguous/polysemous or dramatically different in subjective familiarity compared with the English original. For those plates, the target word was substituted with a word depicted by one of the remaining three pictorial stimuli, having a single dominant meaning in Greek and an estimated familiarity closer to the original English word. Changes in the order of presentation for several items were also deemed necessary based on item difficulty (percentage correct responses averaged across the two pilot data sets). Finally, a more lenient stopping rule (eight failures in 10 consecutive trials) was adopted to increase the sensitivity of the measurements. In case of an incorrect response within the first six items (Items 50–55), the examiner administered items reversely (starting from Item 49), until a basal of 6 consecutive correct responses was reached. It should be noted, however, that only 130 plates were ever administered and these constitute the final full version of the PPVT-R to be used in the age range of Cohort 1 (Items 50–173 plus Items 44–49, which were used only occasionally for reverse administration purposes). Standard administration procedures were used for WISC-III Block Design and Vocabulary subtests.

Selection of items for the short form was based on (a) item–total correlation coefficients and (b) item difficulty estimates obtained using the Rasch model (Rasch, 1980; Smith & Smith, 2004). The latter index was also used to determine changes in the order of presentation for items included in the short form.

Data Analyses

Dimensionality using the Rasch model. Two different methods were used to test the hypothesis that individual variability across PPVT-R items can be modeled by a single underlying factor (Rasch model–based analyses and confirmatory factor analysis [CFA]). Given the dichotomous nature of the data at the item level, the Rasch model may be considered more appropriate. The model postulates that the difference between the ability of the person and the difficulty of the item defines one’s probability of success in solving an item correctly. The formula used to estimate the probability of person n solving item i correctly is

$$P_{ni}(x_{ni} = 1/B_n, D_i) = \frac{e^{(B_n - D_i)}}{1 + e^{(B_n - D_i)}}, \quad (1)$$

where $P_{ni}(x_{ni} = 1/B_n, D_i)$ is the probability of person n getting item i correct (rather than not getting it correct) given a person’s ability B and item difficulty D in logits; $e \approx 2.71828$ (Bond & Fox, 2001; Rasch, 1980; Smith & Smith, 2004; Wright & Stone, 2003). For example, if a very capable person who scores 2 logits on the ability scale encounters an easy item (e.g., with a difficulty level $D = -1$), his or her probability of responding correctly to this item would be 93%. For an item of average difficulty (with $D = 0$), this person’s probability of responding correctly would drop to 88%.

Dimensionality using CFA methods. As an alternative to Rasch model–based analyses, we also tested a one-factor CFA model. Employing the conventional CFA model with polychoric correlations would violate the assumption that the 0–1 scoring of PPVT-R items represents a categorical variable of a truly continuous underlying trait that is normally distributed. To overcome this problem, we used item parceling (Abu-Alhija & Wisenbaker, 2006; Bandalos, 2002; Kisthton & Widaman, 1994; Nasser & Wisenbaker, 2003). To ensure normality and adequate variance across items, random subsets of six items each were created (Holt, 2004), resulting in 29 parcels.

Model invariance across grades using CFA. Given that the issue of dimensionality is of primary importance in the present study, it was crucial to establish that all measured items load on the unitary PPVT-R dimension equally well across grades. Measurement invariance was defined probabilistically as

$$P(X | \xi, G) = P(X | \xi), \quad (2)$$

where X s are the observed scores, ξ is the matrix of latent variables, and G represents group membership (grade). Equation (2) would imply that PPVT-R may be interpreted in a similar fashion as reflecting a single underlying dimension, at least for Grades 2 to 4. We used two complementary methods to evaluate dimensionality: the Rasch model is appropriate with dichotomous data and the CFA would be equally appropriate if used correctly (using item parceling as we did).

Effects of age and gender on PPVT-R total scores. The unidimensionality of the Greek-adapted version of the PPVT-R and the applicability of the single-factor structure across grades (age groups) ensure that it is meaningful to use item–total scores as indices of receptive vocabulary knowledge. We further assessed the effects of demographic variables on this ability using an analysis of variance (ANOVA) on the cross-sectional data with age and gender as the

between-subjects variables. In addition, multiple linear regression analyses were used to compare the magnitude of age effects with previous studies on English-speaking students.

Test–retest reliability, convergent, discriminant, and predictive validity. The stability of PPVT-R scores was assessed on a subset of 500 students who were retested at a 6-month interval (Time 2). The concurrent validity of PPVT-R total scores was assessed based on the matrix of Pearson correlation coefficients between the PPVT-R and scores on another vocabulary measure (WISC-III Vocabulary scale), a measure of nonverbal intelligence (WISC-III Block Design), and various reading achievement measures.

Estimation of item bias using the Rasch model. Bias at the item level was assessed separately as a function of ethnic group (native Greeks, immigrants) and gender on data collected from Cohort 1 (at Time 1). The differential item functioning (DIF) procedure was used, which examines whether the probability of success for a given item varies across groups (see Elder, McNamara, & Congdon, 2004). Given the relatively small size of the immigrant group ($n = 48$), we used the standardized mean difference (SMD) estimate (Wang & Chen, 2004) calculated using the following formula:

$$t_{i1} = \frac{d_{i1} - d_{i2}}{\sqrt{s_{i1}^2 + s_{i2}^2}}, \quad (3)$$

with d_1 and d_2 indicating the probabilities that Group 1 and Group 2 will score correctly on item i and s_{i1} , s_{i2} the standard error for each group. SMD estimates >1.0 were considered significant, indicating the presence of group bias for a particular item (Onwuegbuzie, Levin, & Leech, 2003; Thompson, 1996; Wilkinson & the APA Task Force on Statistical Inference, 1999). All analyses examining differential item functioning were carried out with the Winsteps 3.65 software (Linacre, 2008).

Development of a short form for PPVT-R. Selection of PPVT-R items for construction of a short form of the test was based on estimates of item difficulty (using Rasch model parameter estimates) and estimates of the contribution of the individual scores on each item to the total PPVT-R scores (item–total correlations).

Results

Dimensionality Using the Rasch Model

In the Rasch approach, one conducts an analysis of the residuals and evaluates the extent to which they vary along a single latent dimension as opposed to more than one (Linacre, 2007). Fitting the residuals to a unidimensional model, 98.8% of item variance was explained by the single factor. The remaining variance (1.2%) was modeled as a function of three more factors, each accounting for a negligible proportion ($<1\%$). Thus, the principal components

analysis of the residuals using the Rasch model pointed to the existence of a single dimension in the PPVT-R (see Table 3 for standardized estimates). The Scree plot for the model computed on the entire Cohort 1 data set at Time 1 is shown in Figure 1.

Dimensionality Using CFA

Using the method of parceling described above, the single-factor, 29-parcel model fit the entire Cohort 1 data set collected at Time 1—RMSEA = 4.4% (95% CI = 3.9%–4.8%), CFI = .952, GFI = .906, IFI = .952—although the chi-square statistic was significant, $\chi^2(377) = 795.921$, $p < .01$, as expected with very large sample sizes. All measurement paths were statistically significant at $p < .01$, suggesting their necessity in the stochastic part of the model. The results are shown in Figure 2. The results of conventional analyses were consistent with this conclusion as indicated, for instance, by Cronbach's α for the entire set of items ranging between .92 and .98 across age groups.

Effects of Demographic Variables

Visual inspection of the distribution of individual PPVT-R scores and Kolmogorov-Smirnov tests ($p > .4$ in all cases) indicated good approximation to normality. ANOVAs with gender and age group as between-subjects variables were computed separately for students aged 87 to 123 (for the first four age levels—Time 1 data) and 124 to 147 months (for the remaining three age levels—Time 3 data). In both analyses, there were significant effects of age, $F(3, 518) = 56.03$, $p < .0001$, $\eta^2 = .24$, and $F(2, 284) = 8.03$, $p < .001$, $\eta^2 = .05$, respectively (see Figure 3). The main effect of gender and the age by gender interaction did not reach significance. The linear term for age was significant in both analyses ($p < .0001$; the quadratic term was not significant). Bonferroni-corrected pairwise comparisons between age groups (collapsed across gender) revealed significant ($p < .0001$) increases in mean PPVT-R scores between the following consecutive age groups: 1 (87–95 months)–2 (96–104 months, $p < .0001$), 2 (96–104 months)–3 (105–113 months, $p < .0001$), and 5 (124–131 months)–6 (132–139 months, $p < .006$).

To compare the effects of demographic variables with previous findings reported in the literature, PPVT-R raw score was entered as a dependent variable into a multiple linear regression with age, age², and gender as independent variables, entered in this order. The results of this analysis are shown in Table 4. To facilitate comparisons with the results of Farkas and Beron (2004), we set the intercept at 36 months (i.e., 36 was subtracted from each age prior to the analysis) and gender was coded as 1 for girls and 0 for boys. The results indicate that Greek children gain approximately 1.8 PPVT-R raw points per year within the age range examined. The rate of gain with age is decelerating, as shown by the negative, statistically significant, coefficient

Table 3. Principal Components Analysis of the PPVT-R in the Entire Sample of Cohort 1 at Time 1

Item	Coeff.	Item	Coeff.	Item	Coeff.	Item	Coeff.	Item	Coeff.
34	0.0728	65	0.4299	96	0.4804	127	0.2843	158	0.4001
35	0.0000	66	0.3179	97	0.4875	128	0.4817	159	0.4024
36	0.0000	67	0.3779	98	0.4619	129	0.5553	160	0.3906
37	0.1636	68	0.4316	99	0.3641	130	0.6815	161	0.3311
38	0.1636	69	0.4014	100	0.4006	131	0.2097	162	0.1590
39	0.1033	70	0.2602	101	0.4178	132	0.4384	163	0.1086
40	0.1636	71	0.1981	102	0.4356	133	0.3241	164	0.3099
41	0.1953	72	0.4860	103	0.2768	134	0.6705	165	0.2477
42	0.1444	73	0.4696	104	0.3451	135	0.6628	166	0.3610
43	0.2180	74	0.3215	105	0.3755	136	0.3388	167	0.2250
44	0.1922	75	0.4862	106	0.5766	137	0.3144	168	0.2322
45	0.2284	76	0.3442	107	0.5239	138	0.4177	169	0.1968
46	0.2650	77	0.3468	108	0.4199	139	0.6491	170	0.2979
47	0.2984	78	0.4987	109	0.6006	140	0.5362	171	0.2490
48	0.0984	79	0.4893	110	0.5103	141	0.4165	172	0.2491
49	0.1114	80	0.3709	111	0.4405	142	0.4448	173	0.2956
50	0.0840	81	0.3760	112	0.4212	143	0.3511		
51	0.1934	82	0.2399	113	0.2762	144	0.0337		
52	-0.0000	83	0.2756	114	0.4038	145	0.4238		
53	0.2310	84	0.4713	115	0.4304	146	0.3322		
54	0.3175	85	0.2746	116	0.5654	147	0.1492		
55	0.0723	86	0.4433	117	0.3161	148	0.1065		
56	0.2490	87	0.4143	118	0.4506	149	0.4268		
57	0.4188	88	0.4553	119	0.6659	150	0.2880		
58	0.2818	89	0.5094	120	0.4712	151	0.3393		
59	0.3217	90	0.4173	121	0.3236	152	0.4517		
60	0.0941	91	0.4316	122	0.6599	153	0.4071		
61	0.2730	92	0.4735	123	0.6128	154	0.4887		
62	0.3446	93	0.3720	124	0.6502	155	0.3088		
63	0.3753	94	0.5538	125	0.6089	156	0.1402		
64	0.2952	95	0.4731	126	0.2426	157	0.4931		

Note. PPVT-R = Peabody Picture Vocabulary Test-Revised.

for the quadratic trend. Our estimates for the linear and quadratic effects of age are similar to those of Farkas & Beron. In particular, their estimates for age effects lie within our corresponding 95% confidence intervals. As in the preceding analyses, no significant gender effects were found. Although girls apparently scored 1.2 points lower than boys on average according to this analysis, which is in the opposite direction from the findings of Farkas and Beron, the corresponding coefficient was not statistically significant, and inclusion of gender in the equation accounted for a negligible additional 0.1% of PPVT-R variance. Finally, we compared our estimated PPVT-R raw scores (using the regression coefficient shown in Table 4) to estimated scores using the corresponding coefficients from Farkas and Beron (also shown in Table 4), calculated at monthly intervals between the ages of 88 and 146 months. Our estimates were on average 17.8 points higher than those of Farkas and Beron. This difference was quite stable (maximum deviation = 2.0 points, RMS = 0.750), as expected from the close match between the age effects coefficients.

Test-Retest Reliability, Convergent, Discriminant, and Predictive Validity

The 6-month test-retest correlation coefficients for the total PPVT-R score ranged between $r = .65$ and $r = .86$ across age groups. The stability of raw scores for students with Block Design standard scores < 5 ($N = 19$) was also very high ($r = .86$).

Correlation coefficients at Time 1 between PPVT-R (age-corrected z scores) and WISC-III subtest standard scores were, as expected, greater for Vocabulary ($r = .56$) than Block Design ($r = .33$). Moreover, PPVT-R scores were stronger predictors of reading comprehension ($r = .56$) than were word reading accuracy ($r = .36$) or pseudoword reading accuracy ($r = .19$), regardless of age. These relations were quite stable over time: at Time 3 correlation coefficients of PPVT-R scores with WISC-III Vocabulary, Word Reading Accuracy, Pseudoword Reading Accuracy, and Reading Comprehension scores were $r = .62$, $r = .22$, $r = .35$, and $r = .43$, respectively (Block Design was not administered at Time 3).

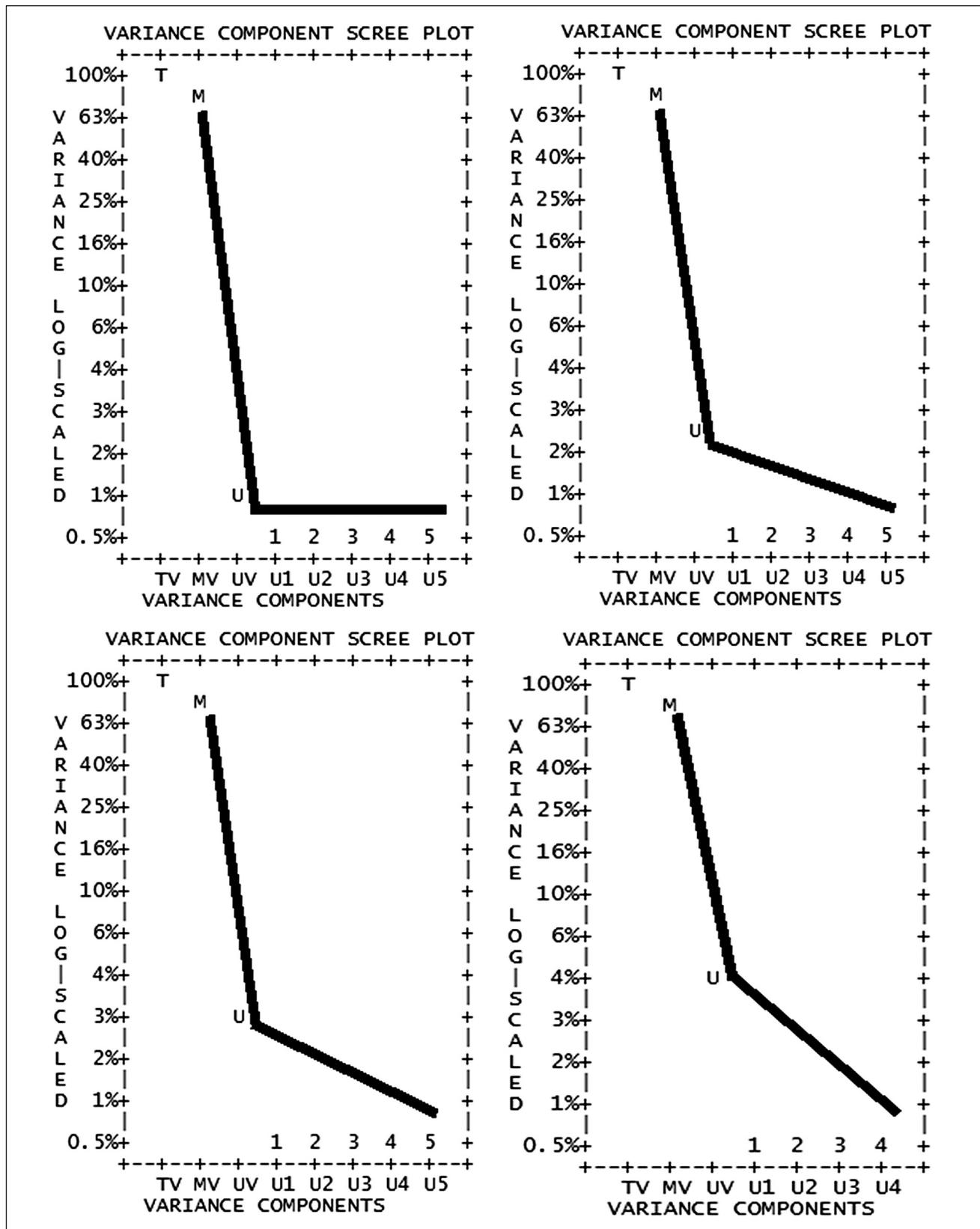


Figure 1. Scree plots showing amount of variance explained by various factors for the full sample (upper left panel) and separately for each grade (Cohort 1)
 Note. All plots show the existence of one major dimension accounting for large amounts of variance.

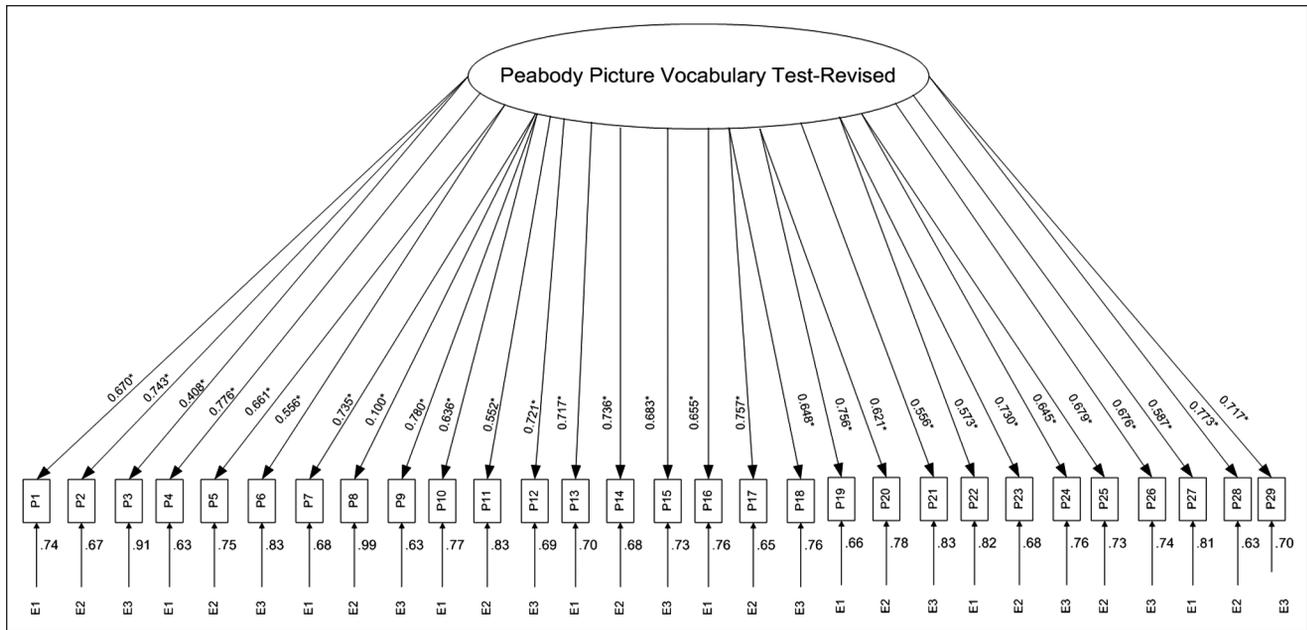


Figure 2. Confirmatory factor analysis model with parceled items (n = 6)

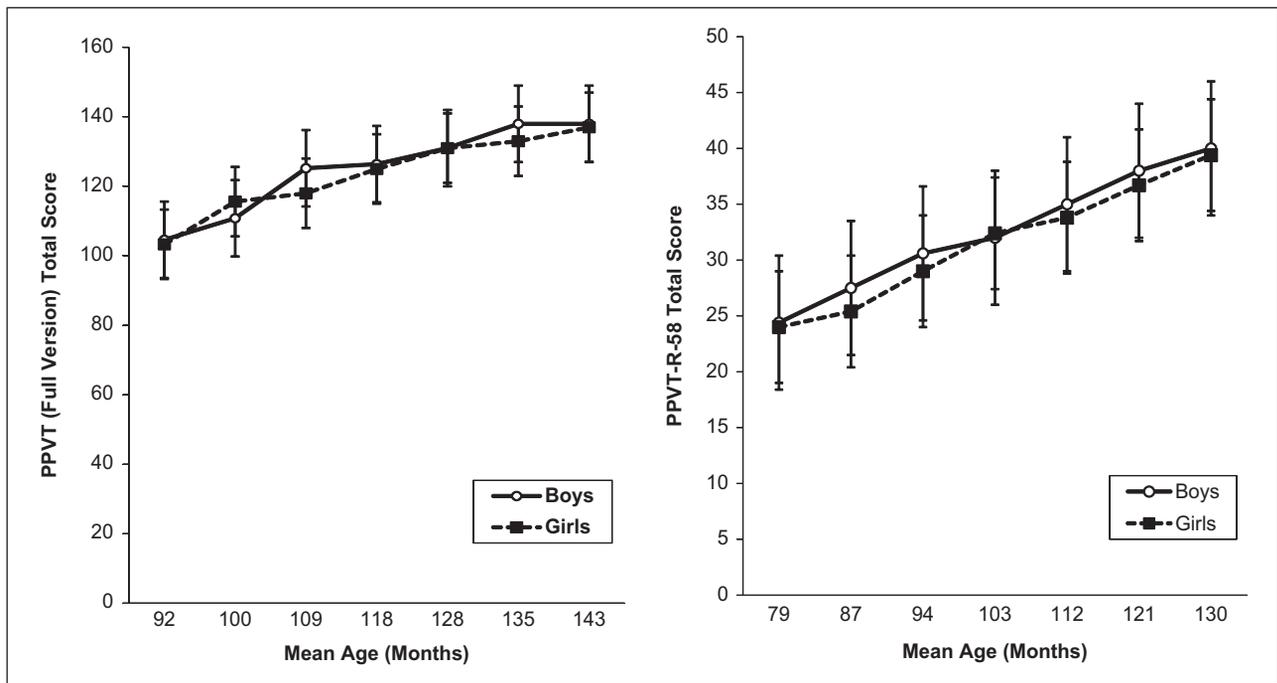


Figure 3. Mean scores by age and gender for the Peabody Picture Vocabulary Test-Revised (PPVT-R) (left panel) and the PPVT-R-58 (right-hand panel)
 Note. Bars represent SD values.

Item Bias of the PPVT-R by Gender

On average, gender differences on PPVT-R standard scores were minimal ($z_{boys} = .13 \pm .92, z_{girls} = .09 \pm .92, p = .6$). Using the Rasch model, differential item functioning was

observed for 12 items, of which six (78, 90, 91, 120, 135, 141) were easier for boys than for girls, and six (115, 116, 132, 137, 140, 168) were easier for girls. The biased items represented a small percentage (6.9%) of all the items of the scale (see Figure 4). Furthermore, the direction of bias

Table 4. Results of Multiple Linear Regression Analysis Predicting Raw PPVT-R Scores From Age (in Months, Minus 36) and Gender (Female = 1)

Regression Term	B	p	95% Confidence Interval ^a		ΔR^{2b}	F & B ^c
Constant	25.792	.017	4.674	46.911	—	22.459 ^d
Age	1.833	<.0005	1.298	2.368	.351	1.413
Age ²	-.007	<.0005	-.011	-.004	.012	-.005
Gender	-1.196	.179	-2.940	.549	.001	.986

Note. PPVT-R = Peabody Picture Vocabulary Test–Revised.

a. Low and high bound of the 95% confidence interval for B.

b. Additional variance accounted for when each variable is entered alone in the order indicated (Age at Step 1, Age² at Step 2, and Gender at Step 3).

c. Corresponding coefficients from growth modeling by Farkas and Beron (2004, Table 2, p. 497).

d. To allow comparison despite a larger number of predictors in the Farkas and Beron (2004) study, this intercept was calculated by adding to their estimated intercept (11.897) the sum of their average effects except for Age, Age², and Gender, calculated as the product of each coefficient on their Table 2 (p. 479, 1st column—excluding SES) times the corresponding mean value on their Table 1 (p. 478). Race effects were excluded from this calculation, by setting Black = 0 and ignoring main effect and interaction coefficients involving race. Thus, the above values correspond to estimates for Whites.

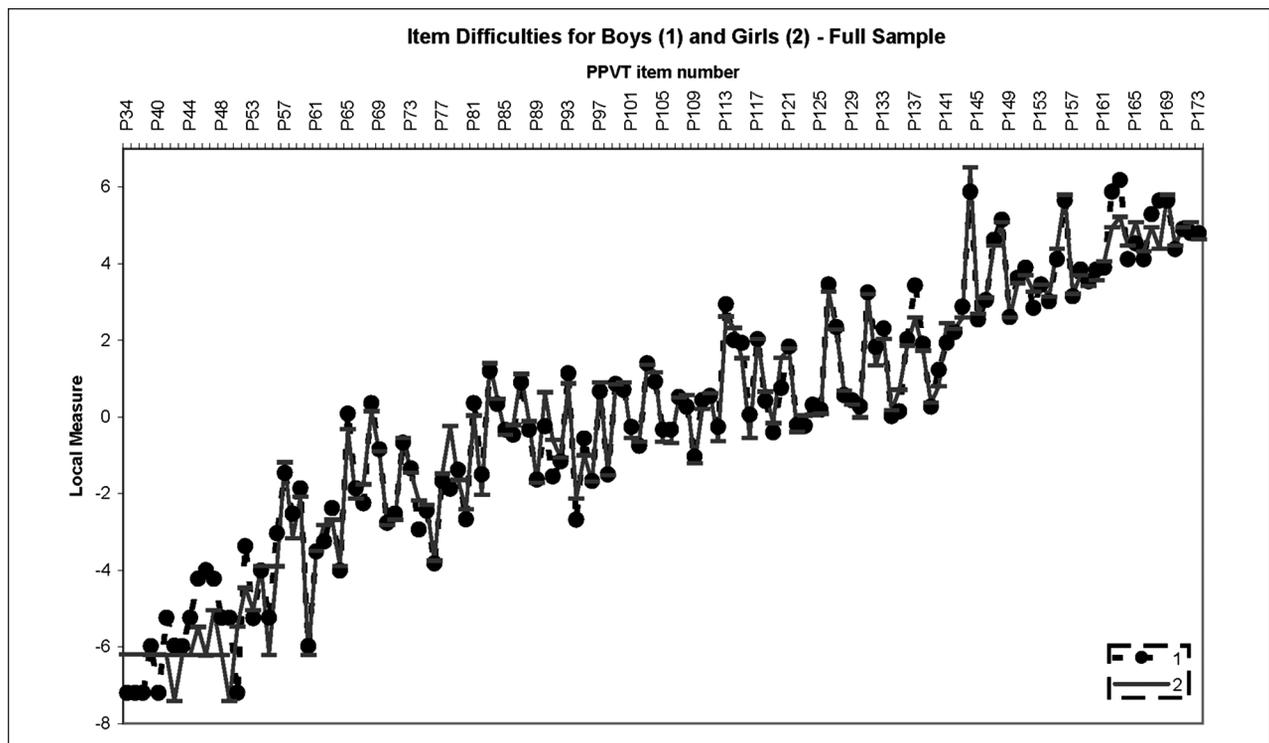


Figure 4. Differential item difficulties for boys (solid dark line) versus girls (dashed light line) for the full sample

was not consistent, as relatively easier and more difficult items were found for both genders. Thus, there was no specific pattern of bias across genders (i.e., the scale did not consistently favor one gender group compared to the other).

Item Bias of the PPVT-R by Ethnic Group

The average difference between students of Greek origin and immigrants was about 1 SD, $z_{Greeks} = .09$, $z_{immigrants} = -.92$, $F(1, 583) = 51.06$, $p < .0001$, $\eta^2 = .08$. This difference

remained essentially unaltered at the 6-month retest, $z_{Greeks} = .09$, $z_{immigrants} = -.91$, $F(1, 499) = 43.62$, $p < .0001$, $\eta^2 = .08$. DIF analyses across ethnic groups indicated potential group bias for a small percentage of items (11%, see Figure 5). Immigrant students demonstrated significantly lower success probability on items 54, 61, 69, 75, 76, 86, 94, 97, and 119 (absolute DIF contrast values exceeded .79 in all cases). The opposite trend (immigrant students having a higher probability of correct responses) was found for items 63, 66, 82, 85, 99, 104, 128, 131, 146, and 162 (absolute DIF contrast val-

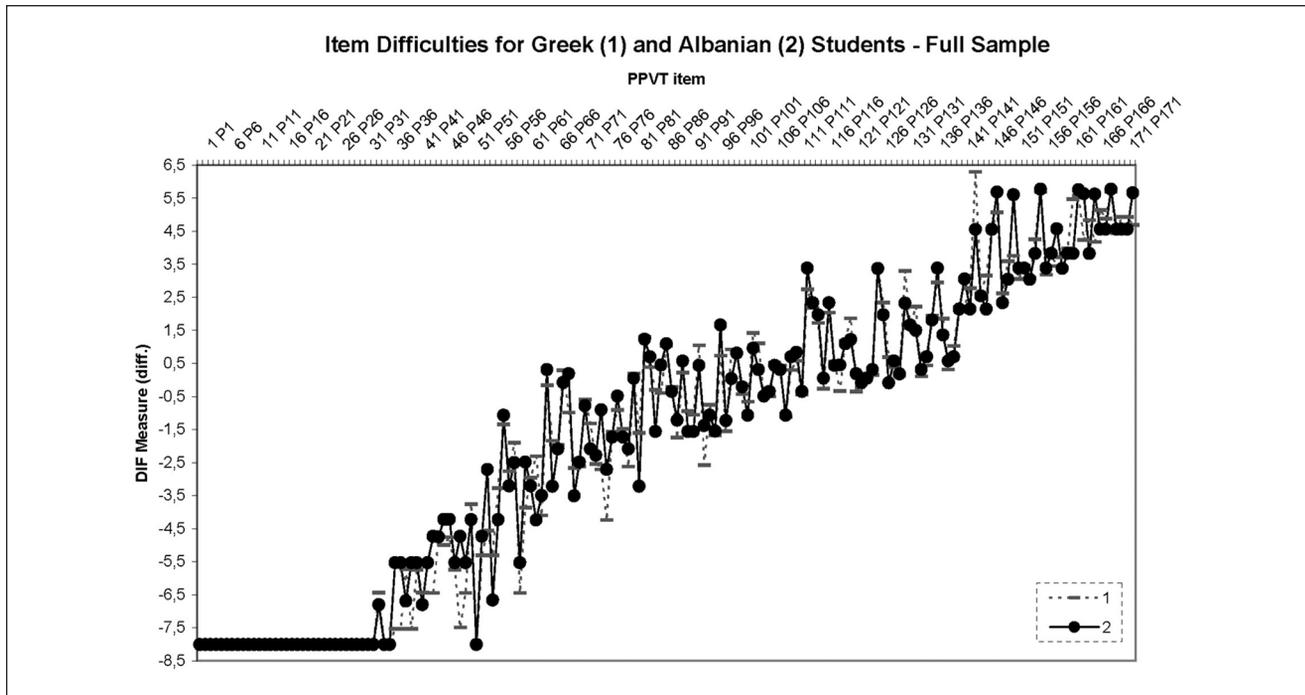


Figure 5. Differential item difficulties for Greek students (solid dark line) versus non-Greek students (dashed light line) for the full sample (Cohort 1)

ues exceeded .77 for these items). Overall, these findings do not reveal a specific pattern of bias against or in favor of a specific ethnic group, given that variations in performance occurred in both directions.

Item Difficulty-Development of Short Form

Items were initially ranked based on item difficulty (Rasch model parameter estimates computed for the entire Cohort 1 data set obtained at Time 1; see Figure 6). Items associated with perfect scores in the 87- to 93-month age group and zero variance were eliminated first. Items with item-total correlations less than .2 were also eliminated, leaving 58 items. The final list of items for the short form was derived by selecting 1 to 2 items from item clusters with similar difficulty indices. To further reduce administration time, different starting points were set for different age groups (the item following a series of items associated with 95% or more correct responses). Tentative starting items were set as follows: Item 1 for the 75- to 90-month groups, Item 8 for the 91- to 98-month group, Item 13 for children aged 99 to 107 months, Item 18 for ages 108 to 116 months, and Item 24 for the 117- to 134-month age range. The reverse administration rule required four correct answers in the first five items administered.

Short and Full Version Equivalence

Short and full forms were closely equivalent as indicated by correlation coefficients ranging between .96 and .97 across

grades (computed on Cohort 1 data). Moreover, cross-sectional effects of age on PPVT-R-58 scores (Cohort 2 data) were very similar to those found for the full version of the test (Cohort 1) as shown in Figure 1. This tentative conclusion was confirmed by ANOVAs with gender and age group as between-subjects variables, computed separately for students aged 75 to 134 (for seven age groups) based on Cohort 2 data. A significant effect of age was found, $F(6, 909) = 89.05, p < .0001, \eta^2 = .37$. The main effect of gender and the age by gender interaction did not reach significance. The linear term for age was significant ($p < .0001$), whereas the quadratic and higher order terms were not. Bonferroni-corrected pairwise comparisons between age groups (collapsed across gender) revealed significant increases in mean PPVT-R-58 scores between the following consecutive age groups: 2 (83–90 months)–3 (91–98 months, $p < .002$), 5 (108–116 months)–6 (117–125 months, $p < .004$). A separate ANOVA on Cohort 2 PPVT-R-58 data including six age groups spanning 83–125 months of age (approximately the same age range used in the ANOVA performed on Cohort 1 data) revealed a virtually identical age effect size, $F(4, 651) = 47.76, p < .0001, \eta^2 = .22$.

Discussion

Based on pilot data, extensive changes were considered necessary in adapting the PPVT-R in Greek. These changes involved eliminating two plates that contained unfamiliar objects for Greek participants, changing the target stimulus (and corresponding word) on 44 plates, and modifying the

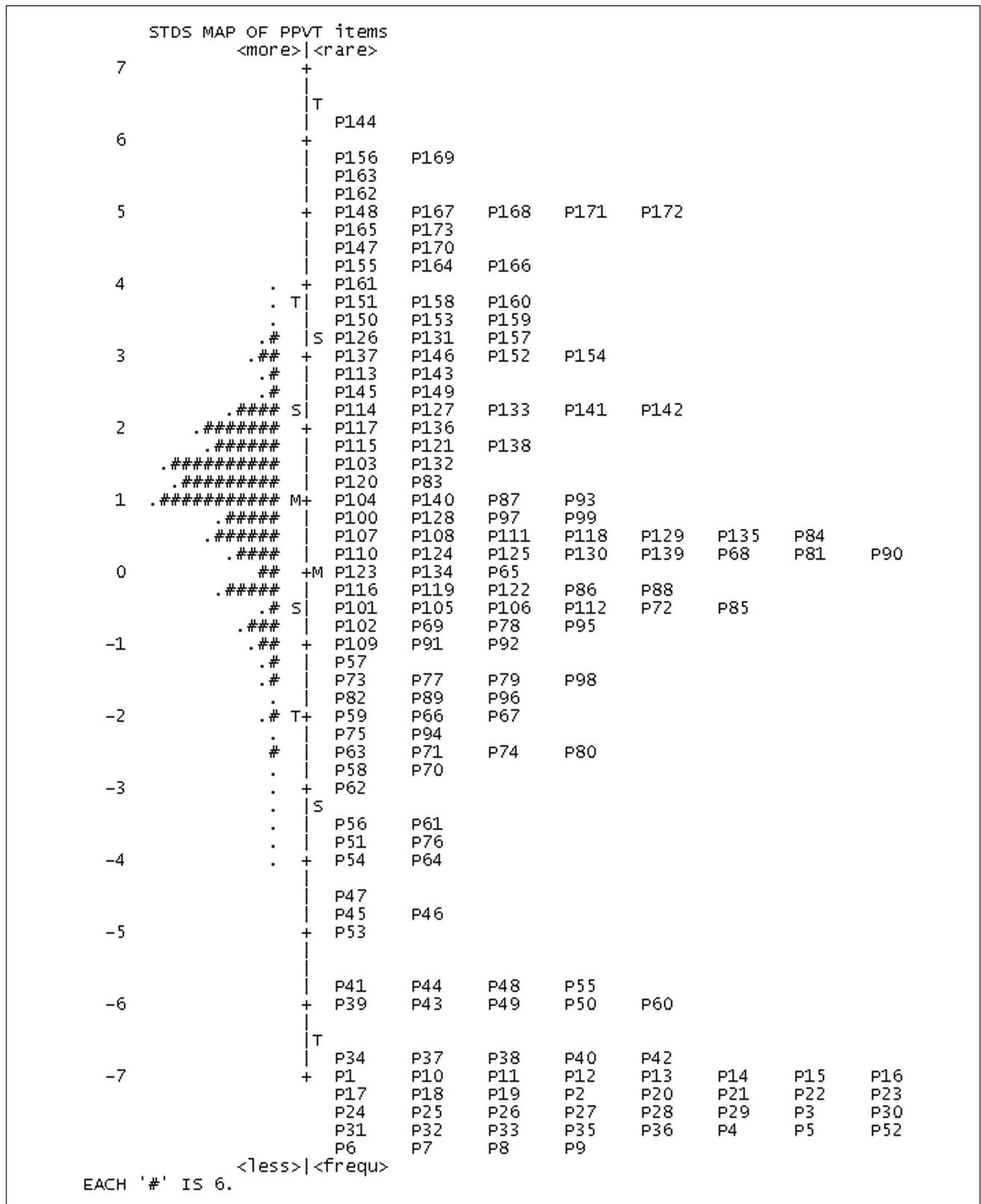


Figure 6. Item difficulty indices for PPVT-R computed using the Rasch model for the entire sample (Cohort I)

order of plates. Further changes in the order of stimuli were suggested on the basis of the normative data, enabling the use of tighter ceiling rules to reduce testing time when administering the short forms. The latter may serve as a viable alternative to the full (Greek) version of the PPVT-R in view of the near-perfect correlation coefficient between short and full forms. It should be noted that these changes rendered the Greek adaptation of the PPVT-R somewhat "easier" than the original English version, as indicated by the fact that mean raw scores on the former were 16 to 20 points higher than mean raw scores on the latter across age groups represented in both standardization samples, despite the fact that the Greek version of the test consisted of only 173 items.

With respect to basic psychometric properties, the Greek (full) version of PPVT-R displayed adequate internal consistency, and long-term (6-month) test-retest stability, which was essentially identical to that reported in previous studies for the same age range (reviewed by Bochner, 1978). In the present data set, long-term stability was similar, or slightly better, for children with lower estimated IQs. Convergent validity estimates obtained in the present study were compatible to those reported in previous studies: correlation coefficients between the Greek PPVT-R and WISC-III Vocabulary were found to be .56 and .62 over two measurement waves. The median coefficient between PPVT-R total score and WISC-III Vocabulary across studies was .69 (range: .37 to .83; L. M. Dunn & Dunn, 1981). In more recent studies using the PPVT-R in English-speaking clinical samples, coefficients in the order of .79 (Rosso, Falasco, & Phelps, 1984) and .50 (Zagar & Mead, 1983) have been reported. Correlations between PPVT-R and WISC-III Block Design subtest scores in those studies were .54 and .40, respectively, compared to .33 in the present study. Predictive validity estimates of the Greek version of PPVT-R were also similar to those reported for PPVT scores (for concurrent measurements in all cases): correlation coefficients between PPVT-R and reading comprehension scores in the present study were .43 and .56 (across two waves) compared with median coefficients of .66 (range: .42 - .70) with the Reading Comprehension index from the Peabody Individual Achievement Test (English version; L. M. Dunn & Dunn, 1981). The predictive value of the Greek version of PPVT-R appears to be significant as well, given that, in the context of longitudinal studies, PPVT-R score appears to be the most important predictor of reading (passage) comprehension, contributing unique variance to the latter outcome measure along with WISC-III Vocabulary scores (Mouzaki, Sideridis, Simos, & Protopapas, 2007; Protopapas, Mouzaki, et al., in press).

With regard to dimensionality, the PPVT-R proved to represent a single latent vocabulary dimension. Rigorous Rasch modeling at the item level suggested that almost all of the items' variance reflected a single latent dimension. The unidimensionality of the PPVT-R was further supported by

confirmatory factor analysis using parceled items. All estimates (except chi-square, which is affected by excessive power) were satisfactory (particularly the residuals). The dimensionality of PPVT-R has not been previously examined using confirmatory models. Miller and Lee (1993) tested the construct validity of the PPVT-R but did not use data at the item level. Instead, they modeled three parameters of the words, that is, word length, polysemy, and frequency of usage.

With regard to measurement invariance, the findings were impressive as all but three factor loadings (of 84) were equivalent. This suggests that the function of items (at the parcel level) as indicators of the latent trait was extremely similar across the three age groups. This finding counters the possibility that later (more difficult) items are more important in the definition of the trait compared to easier items and that this would be manifested with younger versus older students. Thus, we expected that some noninvariance could be attributed to developmental factors. Nevertheless, that was not the case suggesting that the present Greek adaptation of the PPVT-R performs consistently across Grades 2 to 4.

With regard to the presence of bias on the PPVT-R, there were very few gender-biased items (6.9%), and the directionality of the bias was evenly divided between the two genders. Similarly, little and nonconsistent bias was observed with regard to cultural/ethnic background despite considerable differences between groups on total raw scores. Thus, the present findings suggest little item-level bias by the Greek version of the PPVT-R in accordance with the few other studies that examined systematic item bias on PPVT tests for different ethnic/cultural groups (PPVT-III; Restrepo et al., 2006).

Significant age effects on raw PPVT-R scores were found, as expected, between consecutive age groups spanning a wide age range (87–139 months of age). Importantly, age effect sizes were similar for the full and short versions of the PPVT-R, further supporting the equivalence of the two tests. Age effects were very similar to those reported in large-scale studies in English-speaking populations (Farkas & Beron, 2004).

To summarize, item-level analyses suggested that the Greek adaptation of the PPVT-R (a) is culturally appropriate for the assessment of a single underlying dimension of vocabulary knowledge, (b) can provide unbiased estimates of this knowledge even for special cultural subgroups (children born in immigrant families) whose primary language is Greek, and (c) can be used in a short form either as a screening tool or as part of a comprehensive psychoeducational assessment battery where administration time is crucial. Given the extensive modifications that were deemed necessary in the order of items and the identity of several target words, we suggest that detailed item-level analyses of the normative data are necessary for future adaptations of

this and other language assessment tools in Greek and other languages and cultures.

Finally, the importance of adapting and using tests specifically targeting vocabulary knowledge as part of comprehensive assessment batteries for students with print-related learning difficulties rests on the crucial role of both oral and written language skills in comprehending written text. Strong vocabulary knowledge has been shown to facilitate fluency and reading comprehension (Dixon et al., 1988; Frost et al., 2005; Vellutino et al., 2007; Yovanoff et al., 2005) and to exhibit strong genetic correlation with comprehension as well as shared environmental variance by Grade 4 (Olson et al., 2011). According to one hypothesis, vocabulary breadth (number of word meanings known) is the decisive factor for text understanding (Anderson & Freebody, 1981; Stahl & Fairbanks, 2006). The accumulated evidence on reading comprehension gains attributed to vocabulary instruction, as presented by the report of the National Reading Panel (National Institute of Child Health and Human Development, 2000), which included vocabulary as one of the essential components for developing reading comprehension, has already enhanced the share of vocabulary instruction in school curricula. Evaluations of student skill development and progress monitoring will ensure early identification of students with language and reading comprehension challenges and direct the allocation of extra resources (both within and outside the classroom). Standard tests of receptive and expressive vocabulary seem to provide a reasonable starting point, as they have been shown to serve as strong, complementary predictors of reading comprehension (Oakhill et al., 2003; Yovanoff et al., 2005). The PPVT-R, and especially its short form, may serve as a viable alternative to more time-consuming and demanding vocabulary tests—in terms of administration and scoring procedures—with the added advantage that it can be administered by trained special educators as part of a brief assessment battery. To this end, we hope that our work helps support the validity of receptive vocabulary assessment tools such as the PPVT-R and also provides a model for future adaptations in other languages and applications in diverse settings and cultures.

Declaration of Conflicting Interests

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