Universal Scale of Intelligence -Estimated (USIE): Representing intelligence estimated from level of education

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Abstract

In clinical neuropsychology, it is often necessary to estimate a patient's premorbid level of cognitive functioning in order to evaluate whether his scores on cognitive tests should be considered abnormal. In practice, test results from before the onset of brain pathology are rarely available, and the patient's level of education is used instead as an estimate of his premorbid level. Unfortunately, level of education may be expressed on many different scales of education, which are difficult to use interchangeably. Here, we introduce a new scale that has the capacity to replace existing scales and can be used interchangeably with any of them: the Universal Scale of Intelligence Estimates (USIE). To achieve this, we propose to map all levels of existing educational scales to standard IQ scores. This USIE point estimate is supplemented with an estimation interval. We assert that USIE offers some important benefits for clinical practice and research.

Keywords

premorbid IQ, educational scale, clinical evaluation, education comparison, adjusted level of education, demographic variables

In most clinical neuropsychological assessments, some estimate of the level of patients' cognitive functioning prior to the onset of their cognitive complaints is required to decide whether a certain test score is abnormal (Lezak, Howieson, Bigler, & Tranel, 2012). Ideally, this level would be summarized by a premorbid IQ score. In practice, however, such a score is rarely available. Instead, the patient's level of education is used as a proxy for his or her (premorbid) level of cognitive functioning. In neuropsychological research, it is also common to use level of education as an indicator of cognitive functioning, for example, as a covariate in statistical analyses.

This paper discusses problems that limit the usefulness of level of education as a proxy for premorbid cognitive functioning. We propose a remedy for these problems in the form of a new scale: the Universal Scale of Intelligence Estimates (USIE). This scale will function as an intermediate scale to make comparisons between educational scales possible and will promote a better estimate of premorbid cognitive functioning. Below, we first discuss how level of education is currently used in the clinical setting to estimate premorbid cognitive functioning. Second, we discuss the limitations of the use of level of education in the clinical setting and in neuropsychological research. Third, we describe other solutions that have been proposed for estimating premorbid IQ and their limitations. Fourth, the concept of USIE, its construction, and its benefits are introduced through examples. Finally, we discuss some practical issues related to the construction of USIE and some possibilities for a broader application.

Use of Level of Education to Estimate Premorbid Cognitive Functioning in Clinical Practice

In the absence of actual data on premorbid cognitive functioning, level of education is often taken as an estimate of a patient's premorbid level. This is universally applicable, also in case of severe impairments. Moreover, the normative data of many neuropsychological tests are stratified by level of education, whereas only few tests can be corrected for (premorbid) IQ (Lezak et al., 2012). This has led to frequent use of "level of education" to represent a patient's premorbid cognitive abilities in the diagnostic process.

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Table 1. Level of Completed Education and Corresponding Score on the ISCED (1997) Scale.

ISCED score	Level of completed education
0	Preprimary education
1	Primary education
2	Lower secondary
3	(Upper) secondary
4	Postsecondary, nontertiary
5	First stage of tertiary education
6	Second stage of tertiary education

Note. ISCED = International Standard Classification of Education.

Limitations of Level of Education

Even though level of education is widely used as an indicator of cognitive functioning, it entails a number of problems. Some are of a conceptual nature, whereas others are more practical.

Many Educational Scales. Even in one country, there may be several ways of defining level of education. It may be quantified as number of years of formal education, or in terms of the highest intellectual level of completed education (e.g., "college" or "elementary school"). Comparing values measured on different scales cannot easily be done, and comparing measurements between countries is even more difficult as a particular school type may be unknown in another country. The same scale point, such as "college," may represent a higher intellectual level in one country than in another. In an attempt to remedy this, United Nations Educational, Scientific and Cultural Organization (UNESCO) introduced the International Standard Classification of Education (ISCED; see Table 1; UNESCO, 1997), which codes level of education on a 7-point scale. A more recent ISCED version has a more differentiated scale (UNESCO, 2011). In contrast to this rather fine-grained scale, a rough division into three levels, typically "low," "medium," and "high," is also widely used. Some researchers even decide to construct their own scales for educational levels.

The many different educational scales may cause great difficulties when researchers want to compare data from different studies, for example, in a meta-analysis, if level of education is a variable of interest. Different coding systems may prove impossible to translate into a single, all-encompassing system. For example, when one study uses the ISCED (1997) scale and another study uses education in years, the studies are difficult to compare because there is no straightforward conversion from ISCED (1997) to years of education or vice versa. This problem is often resolved by recoding the finer grained scales into a scale with a lower resolution with categories such as a "low" "medium," and "high." Although such recoding is feasible and easy, it causes loss of information about participants' level of education, which in many situations is undesirable.

Outdated Educational Scales. Some educational scales have become outdated due to changes in educational systems in the course of time. For example, when levels of education or entire school systems are redefined or reformed, the new school system may not fit into the existing scales. To solve this problem, new scales must be created, or the new levels of education have to be forced into scales that were not designed to accommodate them. This poses a challenge for clinical use when test scores are compared with a norm table that is stratified by level of education, because it may introduce inaccuracies. Ideally, norm tables should contain all possible levels of education that are in use today, but also those that were in use when elderly patients went to school, so that we can compare our patients to the correct normative sample. In practice, test norms never include such extended educational tables.

Level of Education as an Ordinal Scale. In research settings, level of education is often used in statistical analyses. Educational levels are coded on an ordinal scale, such as ISCED, and numerically recoded, after which statistics such as average and standard deviation are calculated. On an ordinal scale, however, statistics such as average, standard deviation and correlation are not well-defined, and using them in this manner may give a distorted impression of the population.

Alternative Ways to Estimate Premorbid Level of Functioning

In the absence of actual data on premorbid cognitive functioning, an estimate may be derived from cognitive tests that are relatively insensitive to brain pathology. In this section, we review a number of methods that are used in clinical practice to acquire an estimate of premorbid cognitive functioning.

Cognitive Tests for Premorbid IQ Estimations

Tests such as the National Adult Reading Test (Nelson & O'Connell, 1978) and its U.S. adaptations, that is, the North American Adult Reading Test (Blair & Spreen, 1989) and the American version of the National Adult Reading Test (Grober, Sliwinsk, & Korey, 1991), are used to estimate a patient's premorbid IQ. These tests require patients to read aloud words with irregular orthography. Similar tests are the Wide Range Achievement Test–Word Reading (Wilkinson & Robertson, 2006) and the Wechsler Test of Adult Reading (Wechsler, 2001), which has norms corrected for level of education. A variation on these word-reading tests are tests that use the force–choice format such

as the Spot-the-Word Test (Baddeley, Emslie, & Nimmo-Smith, 1993) or the Lexical Orthographic Familiarity Test (Leritz, McGlinchey, Lundgren, Grande, & Milberg, 2008). What these test have in common is that they rely on word-reading abilities which are relatively spared in many forms of brain pathology and thus can be useful for estimating a patient's premorbid verbal IQ.

Another way to estimate premorbid cognitive functioning is by using information about a patient's background in addition to his level of education. For example, using a regression-based approach to estimate premorbid IQ from demographic variables such as level of education, sex, age, ethnicity, and region of the country (Barona, Reynolds, & Chastain, 1984; Crawford, & Allan, 1997). A combination of both approaches is used by the Oklahoma Premorbid Intelligence Estimation (OPIE-3), which takes into account both the demographic background of a patient as well as Wechsler Adult Intelligence Scale–Third edition (WAIS-III) test data from the subtests Vocabulary, Information, Matrix Reasoning, and Picture Completion (Schoenberg, Duff, Scott, Patton, & Adams, 2006).

There are a number of limitations to these methods. First, the word-reading tests cannot be used in patients with more severe pathology or with a language deficit (such as aphasia or dyslexia). A similar problem occurs with the OPIE-3 estimate as not all patients are able to reliably complete these WAIS-III subtests. Also, the regression-based approaches may be satisfactory in the United States or the United Kingdom where they were developed, but they cannot easily be applied in other countries as the formulas are based on the demographic characteristics of the United States (or the United Kingdom). Also, estimations derived from regression approaches have a tendency to be relatively inaccurate in the outer ranges of the IQ distribution in which higher IQs are often underestimated and lower IQs overestimated (Basso, Bornstein, Roper, & McCoy, 2000). Last, in large scale research projects, it is not always possible to test each participant face-to-face and therefore, gathering a measurement of premorbid IQ is not always possible.

USIE: Universal Scale of Intelligence Estimates

To alleviate these problems, we propose that existing scales of education are replaced by a single universal scale, which uses estimated IQ scores instead of educational level: the Universal Scale of Intelligence Estimates (USIE). The USIE presents mappings from existing educational scales to a (pseudo) IQ score. For example, the mapping of the ISCED (1997) to the USIE can be achieved by collecting IQ scores for each of the 7 points on the ISCED scale. If this is done for a number of different educational scales, we can express each scale in terms of USIE IQ scores. In this manner, all educational scales can be replaced with a single USIE IQ scale, which is used as an intermediate scale. For an example, see the following sections. There are some important advantages associated with the USIE IQ scale, provided the necessary data for its construction are available. The next section focuses on the data required for the construction of the USIE.

Data Required for USIE Construction

To construct USIE, data are required from people whose level of education and IQ have been measured. For example, if we wish to map the ISCED (1997) scale to USIE, we would gather IQ data for each of the 7 points on the ISCED scale. Using the IQ format implies that by definition an IQ score of 100 is equal to a USIE score of 100.

A straightforward approach is to treat level of education as a nominal variable; the USIE scores are tabulated as the median IQ scores for the different levels of education. Medians are used instead of means because IQ scores may not be normally distributed at every educational level. We propose to standardize USIE to the Wechsler Adult Intelligence Scale–Fourth edition (WAIS-IV; Wechsler, 2008), because this is the latest edition of the most widely used IQ scale. Moreover, editions for many languages and countries are available.

Precision of the Estimate

An estimation interval surrounding the USIE score can be constructed corresponding to, for example, the 10th and the 90th percentile of the IQ distribution obtained from the population. The width of this interval is influenced by the resolution of the educational scale being mapped. When a scale has a high resolution, USIE values tend to have relatively narrow estimation intervals. This means that there is relatively little variation in IQ between participants who have the same score on this educational scale. When an educational scale is quite crude (say a 3-point scale), there is generally more variation in IQ scores between participants who have the same score on this educational scale. This leads to a somewhat higher between-participant variance, and thus to larger USIE estimation intervals.

Constructing USIE

To elaborate on our proposal above, we use Dutch WAIS-IV IQ data (Wechsler, 2008) to construct a USIE scale. To create a mapping for application in The Netherlands, the test publisher granted us access to WAIS-IV standardization data and data on the participants' level of education. Levels of education in this WAIS-IV data set were coded on the ISCED scale and were based on 1,172 participants of which 50.9% were female. The data had been collected from August 2010 to May 2011. More detailed information on

Table 2. Descriptive Statistics of the Dutch WAIS-IV Data for ISCED and Low/Medium/High Level of Education.

Level of education	Mean IQ	*SD*	5th Percentile	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	95th Percentile	Female (%)	*N*
ISCED											
0	—	—	—	—	—	—	—	—	—	—	0
1	88.9	21.9	46	53	75	91	104	118	124	56.1	162
2	91.3	13.0	71	75	83	92	100	108	112	53.4	321
3	100.4	13.6	78	83	92	100	110	118	123	50.1	390
4	108.9	12.2	86	94	100	108	116	124	128	49.5	189
5	116.1	12.0	96	101	108	116	126	133	136	36.0	88
6	—	—	—	—	—	—	—	—	—	—	0
Low/medium/high											
Low	88.8	21.9	46	53	75	91	104	118	124	56.1	162
Medium	96.3	14.1	74	79	88	97	105	114	119	52.0	711
High	110.5	12.7	90	95	101	111	119	127	132	45.2	277

Note. WAIS-IV = Wechsler Adult Intelligence Scale–Fourth edition; ISCED = International Standard Classification of Education.

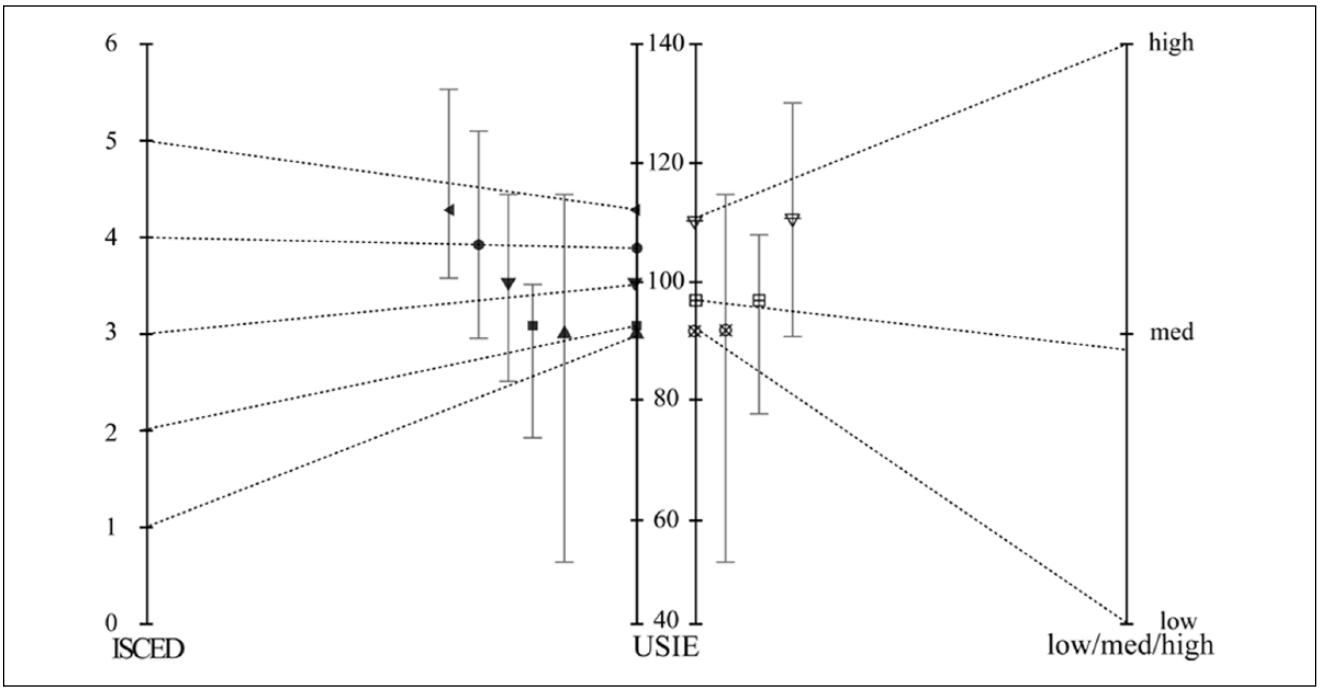

Figure 1. Mapping of the ISCED (1997) scale and an educational scale with lower resolution ("low," "medium," and "high" education) to the USIE scale.

Note. ISCED = International Standard Classification of Education; USIE = Universal Scale of Intelligence Estimates; WAIS IV = Wechsler Adult Intelligence Scale–Fourth edition. For each educational level, the median WAIS-IV IQ and its corresponding 80% estimation interval (i.e., 10th and 90th percentile) are plotted as USIE values. Note that the "0" and "6" scale points of the ISCED (1997) do not have a corresponding USIE; there are no observations in these categories.

this data set can be found in Table 2 and in the Dutch manual of the WAIS-IV (Wechsler, 2008).

Under the assumption that the data from the WAIS-IV have been randomly sampled, we can now create a USIE mapping as drawn in Figure 1 where the median IQs for each level of education on both scales have been plotted. For example, an ISCED (1997) score of 5 maps to a USIE (IQ) score of 116 with an 80% estimation interval of 101 to 133 (see Table 2).

Comparing Educational Scales Through USIE

To illustrate the comparison of two educational scales, we divided the same educational data into the coarse-grained

Table 3. USIE Estimates per Level of Education on the ISCED and Low/Medium/High Scales.

Level of education	USIE	10th Percentile	90th Percentile	*N*
ISCED				
0	—	—	—	0
1	91	53	118	171
2	92	75	108	322
3	100	83	118	393
4	108	94	124	190
5	116	101	133	89
6	—	—	—	0
Low/medium/high				
Low	91	53	118	162
Medium	97	79	114	711
High	111	95	127	277

Note. USIE = Universal Scale of Intelligence Estimates; ISCED = International Standard Classification of Education.

levels of low, medium, and high. This results in two different educational scales that have both been mapped to USIE (see Table 2). We can now compare both scales and visualize their relationship (Figure 1). From Figure 1, it becomes clear that someone who has a "medium" level of education has a USIE score of 97, which is close to an ISCED (1997) score of 3 (= USIE score of 100). Thus, USIE can also function as an intermediary scale. Surrounding each USIE point estimate is an 80% estimation interval. This information can also be found in Table 3.

Discussion

Advantages of USIE

In this article, we introduced the USIE as a new way to represent cognitive level as estimated from level of education. This new scale solves a number of problems with current approaches to estimating (premorbid) cognitive level or intelligence. In this section, we briefly summarize the advantages. In the next section, we discuss limitations that remain and ways to possibly overcome these.

Many Educational Scales. One advantage of the USIE scale is that it allows translation and comparison of scores on different educational scales. If two scales, such as ISCED (1997) and years of education, are mapped to USIE, meaningful comparisons become possible.

Outdated Educational Scales. Because of changes in the educational system, some levels of education that were common decades ago no longer exist today. With USIE scores, this problem can be circumvented. To achieve this, it is necessary to construct mappings of both the outdated and current educational scale(s) to USIE. This also implies the advantage of not having to update test manuals when new educational systems are formed: One can simply measure the IQ of those who have completed the new type (and level) of education.

Level of Education as Ordinal Scale. The USIE is conceived as an IQ score, which is represented on an interval scale. All existing educational scales known to us are ordinal. Converting educational scales into the USIE interval scale allows valid calculation of statistics such as the mean and standard deviation, which are not defined on an ordinal scale.

USIE as Predictor of Premorbid IQ. The USIE can be used as an estimate of premorbid IQ. Unlike word-reading tests such as the National Adult Reading Test or the Wide Range Achievement Test–Word Reading, it is insensitive to brain pathology. Therefore, it can be used even in the most severely affected patients. Another advantage of the USIE is that researchers in any country can create their own mapping to the USIE-scale (which can then be compared between countries). Regression-based estimations of premorbid IQ (such as the Barona method or the OPIE-3) are calibrated to the country they were developed for (the United States) which makes them inapplicable in other parts of the world. Second, most regression-based approaches are inapplicable when not all required demographic variables are available. This is true in particular, when comparing participants between studies such as in meta-analyses in which not all studies collected the same demographic variables. The USIE only requires information about a participant's level of education, which is often available. Third, these regression-based approaches would have to be regularly recalibrated because the demographic characteristics of a country usually change over time. The USIE also has to be recalibrated, but this can more easily be done when publishers of IQ tests incorporate information about the level of education of their normative sample. It would even be done automatically if publishers started to express their normative data in terms of USIE. Last, the USIE score is accompanied by an estimation interval which gives the user extra information about the certainty of the USIE estimate.

Limitations of USIE

As mentioned before, there are many different scales of education. Creating a mapping to USIE for each of those scales is costly because it is labor-intensive and time-consuming to collect sufficient IQ data for all educational scales. However, this investment is worthwhile, because it needs to be done only once for each scale of interest. Also, if the exact level of education and educational degree are collected for each

participant, it would allow mapping to USIE from every imaginable educational scale. For example, if we know that participants have completed a master of science degree, we can use their IQ data to map the ISCED Level 5 (first stage of tertiary education), but also to map the "high" category of the 3-point "low," "medium," "high" educational scale. We would have to collect such fine-grained data only once to make a wide range of mappings to USIE available.

Based on the same principles for comparing different educational scales within one country, USIE could theoretically also be used to compare educational levels between countries. However, we need to be cautious when doing so, because USIE scores are expressed as IQ scores. Consequently, they are dependent on the population characteristics of the country or (sub) culture in which the IQ test was standardized. However, USIE can probably be applied to compare educational levels in countries that are sufficiently similar, such as most Western countries. These applications are nontrivial, and we expect the USIE scale offers a significant improvement, for example, when conducting a study in various European countries, or when conducting a meta-analysis that includes studies from Europe and the United States.

The USIE scale is not influenced by brain pathology. It is based on a demographic factor instead of measurements taken after acquiring brain pathology. This implies, for example, that for a patient with suspected Alzheimer's disease, the USIE scale can give a fair indication of his premorbid cognition because the patient completed his school education prior to the onset of the disease. On the other hand, this also points to a limitation of USIE, namely, its reliance on a fairly normal school career. Because the USIE scale is based on the level of education, premorbid IQ is underestimated for patients who have had a suboptimal school career, for example, due to disease or other personal circumstances. This makes USIE less suitable for application with developmental or congenital disorders such as attention-deficit/hyperactivity disorder, autism, or schizophrenia (see Dennis et al., 2009).

Possibilities of Improving or Extending the USIE Concept

First, for a scale like USIE to be really useful, norm tables for clinical tests need to be specified by (USIE) IQ scores instead of by level of education as is currently the case. Even better would be to replace existing norm tables with regression-based norms, where USIE can be included as a covariate (Crawford & Allen, 1997; Testa, Winicki, Pearlson, Gordon, & Schretlen, 2009).

Second, when level of education is used as a proxy for premorbid cognitive abilities, one has to be aware that education by itself only has a limited correlation with cognitive functions. For example, education and IQ correlate in the order of .55 to .65 (e.g., Barona et al., 1984; Crawford & Allan, 1997; Crawford, Millar, & Milne, 2001; Harnett, Godfrey, & Knight, 2004; Matarazzo, 1972; Wilson, Rosenbaum, Brown, Rourke, & Grisell, 1978). In research and clinical practice, however, level of education is often accepted as a-good-enough estimate of general cognitive functioning. This could lead to gross underestimation of a patient's premorbid level of functioning. For example, premorbid level might be estimated way too low in case of elderly women who have had few years of formal education because they were not given the opportunity to study. Their level of education may be quite low, while their IQs are (above) average. Researchers and clinicians can keep this in mind, and possibly create separate USIE estimates for men and women in specific age bins.

Concluding Remark

Level of education has long been used to estimate (premorbid) level of cognitive functioning, but the variation in educational scales hampers research and clinical practice. We have argued that the USIE scale facilitates meta-analyses and other types of research, and better supports clinical decision making. Clearly, much work needs to be done to map educational scales to USIE. Once this has been completed, meta-analyses will no longer be hampered by diverging scales of education, and comparison of cognitive studies in different Western countries becomes more feasible.

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