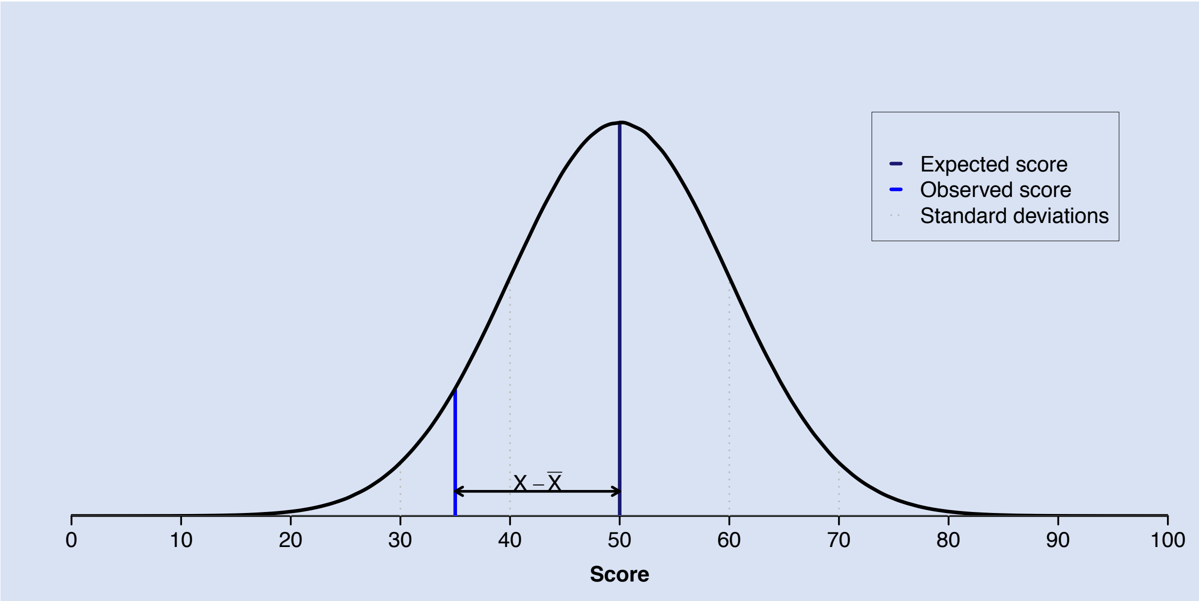
Supplementary materials 1

1. Calculation of z-scores using a stratified sample mean as expected score



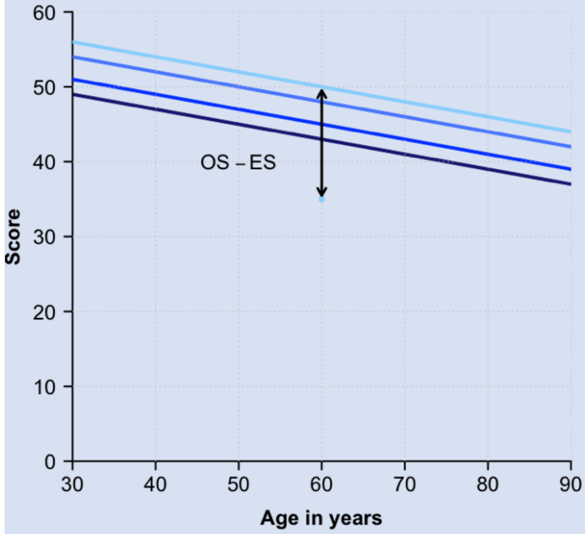
Supplementary figure 1. Derivation of *z*-scores using stratified sample mean

First, normative data were derived using the method that traditionally is used for the derivation of ECAS norms, which assumes that scores are normally distributed. If this assumption holds a patient's score, i.e. the observed score, can be expressed as a *z*-score using the expected score and the standard deviation of the scores in a sample of controls with the same relevant characteristics as the patient. The expected score for a patient is the mean score in a sample of controls with the same relevant characteristics as the patient. This score expresses the distance between a patient's score and his expected in standard deviations and can be calculated using the formula:

$$z = \frac{X - \bar{X}}{\sigma}$$

where z = standard score, X = observed score, $\bar{X}$ = expected score, i.e. the mean score in the stratified sample, and σ = standard deviation of scores in the stratified sample.

2. Calculation of z-scores using the on expected score derived from a (multiple) linear model



Variable	β
Intercept	55.00
Age (in years)	-0.20
Sex, female	2.00
Level of education, higher	5.00

Supplementary figure 2. Derivation of *z*-scores using multiple linear regression.
OS = Observed score; ES Expected score.

Secondly, normative data were derived using multiple linear regression models. The advantage of the multiple linear regression model is that it is not necessary to stratify of the normative sample to correct for factors that are associated with the outcome. Moreover, the multiple linear model facilitates the use of continuous variables and makes the categorisation of individuals based on arbitrary cut-offs redundant. If the assumption of normally distributed scores holds a patient's score, i.e. the observed score, can be expressed as a *z*-score using the expected score and the estimated standard deviation of residuals scores in a sample of controls using the formula:

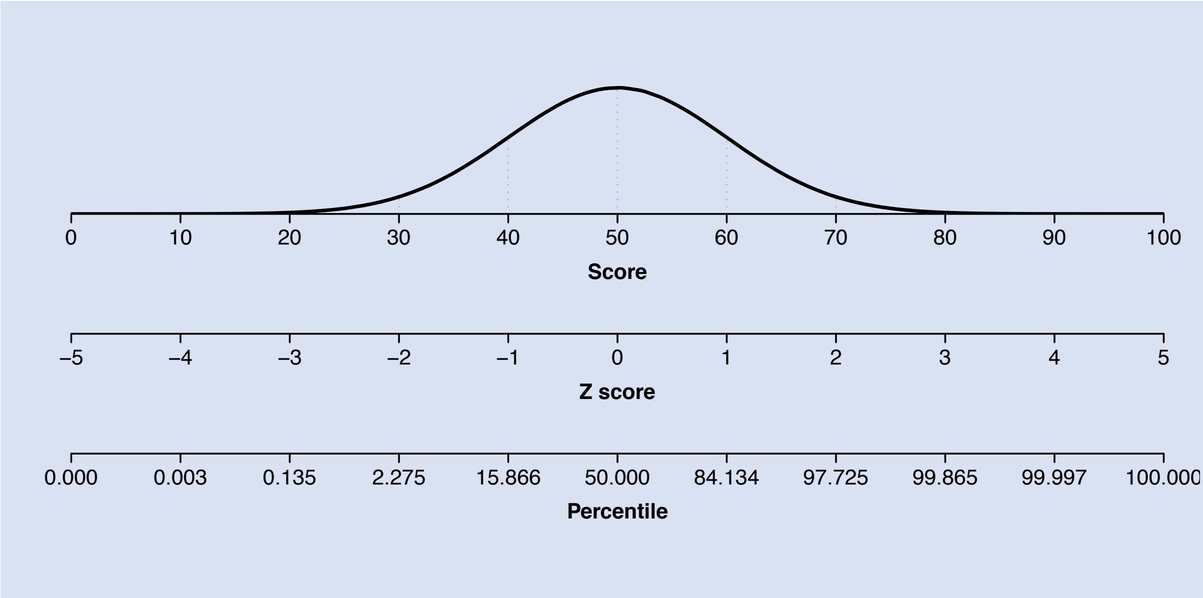
$$Y = \beta_0 + \beta_1 X_1 + \cdots + \beta_n X_n + \varepsilon$$

$$\varepsilon = Y - \bar{Y}$$

$$z = \frac{\varepsilon}{\sigma(\varepsilon)}$$

Where Y = observed score, $\bar{Y}$ = expected score, β_n = regression coefficients, X_n = regressors, ε = residual, z = standard score, and $\sigma(\varepsilon)$ = estimated standard deviation of the residuals.

3. Derivation of percentile scores from normal distributions



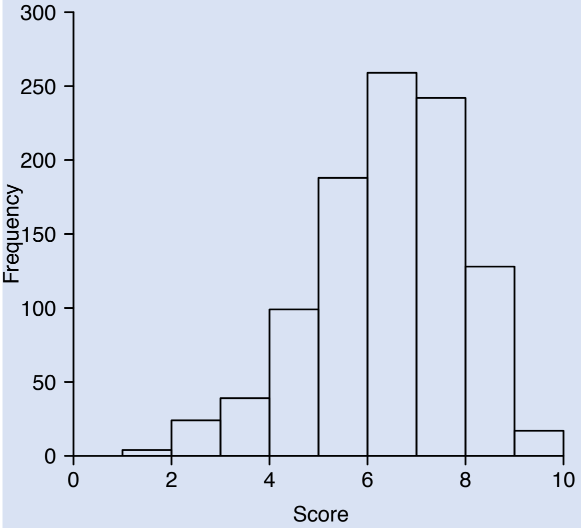
Supplementary figure 3. Derivation of percentile scores from normal distributions

Z-scores can be expressed as percentiles under the assumption of normally distributed scores. The advantage of percentiles is that they directly express how common or uncommon the observed score is in the sample of controls. Percentiles can be calculated from cumulative probabilities with:

$$F(x) = \int_{-\infty}^{x} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

Where $F(x)$ = cumulative probability of x, x = observed score, μ = expected score, and σ = standard deviation. The cumulative probability × 100 is the percentile.

4. Derivation of percentile scores from non-normal distributions



Score	k	m	%
1	1	0	0.05
2	3	1	0.25
3	24	4	1.60
4	39	28	4.75
5	99	67	11.65
6	188	166	26.00
7	259	354	48.35
8	242	613	73.40
9	128	855	91.90
10	17	983	99.15

N = 1000

Supplementary figure 4. Derivation of percentile scores from non-normal distributions

Thirdly, normative were derived in a stratified sample using a nonparametric method for calculating percentiles. There are several definitions of percentiles in neuropsychology, but there are calls for adopting the definition below:

$$\text{Percentile rank} = \frac{m + .5k}{N} 100$$

where *m* is the number of members of the normative sample scoring below a given score, *k* is the number obtaining the given score, and *N* is the size of the stratified sample of controls [1].

Finally, normative data were derived by applying the formula above to the residuals of the multiple linear regression. In this manner, it is not necessary to stratify the normative sample.

References

1. Crawford JR, Garthwaite PH, Slick DJ On percentile norms in neuropsychology: Proposed reporting standards and methods for quantifying the uncertainty over the percentile ranks of test scores. Clin Neuropsychol 2009;23:1173–1195.