Supplemental Material: Converting the Ages and Stages Questionnaire 3rd edition (ASQ) Score to a Developmental Quotient (DQ) Z-score

Introduction

Here we describe our novel method to convert an ASQ score to a DQ z-score. We estimate the DQ z-score given the ASQ score by 1) estimating the DQ score given the ASQ score, 2) adjusting the DQ score based on the child's age and test appropriate age, and 3) converting the adjusted DQ score to a DQ z-score.

Developmental Quotient (DQ) Estimation

Developmental Quotient Z-Score

To estimate the DQ z-score (DQ^z) note that DQ^z is defined as:

$$DQ^z = \frac{DQ - \mu^{DQ}}{\sigma_{DQ}} \tag{1}$$

where, by definition, $\mu^{DQ} = 100$, $\sigma_{DQ} = 15$, and DQ is calculated using:

$$DQ = 100\frac{Age^e}{Age^a} \tag{2}$$

where Age^e is the administered test equivalent age and Age^a is the child's age at the time of the administered test. We can rearrange equation (1) and express DQ as a function of DQ^z, i.e.,

$$DQ = (DQ^z)(\sigma_{DQ}) + \mu^{DQ} \tag{3}$$

ASQ Z-Score

The ASQ z-score (ASQ^z) is defined as:

$$ASQ^z = \frac{ASQ - \mu^{ASQ}}{\sigma_{ASQ}} \tag{4}$$

where μ^{ASQ} and σ_{ASQ} were obtained from a Brazilian publication (Filgueiras, Pires, Maissonette, & Landeira-Fernandez, 2013), by age class, and ASQ is the score from the child's ZODIAC administered test. Our goal is to convert the ASQ to a DQ^z.

ASQ^z to DQ^z Conversion Factor

The main text (Figure 2) provides the information to calculate the ASQ^z to DQ^z conversion factor. Note in Figure 2 that when $ASQ^z = -1.5$ the corresponding developmental delay (DD) value is 25%. By definition, $DQ = 100 - DD = 75$. Using equation (1) we calculate DQ^z given $DQ = 75$, i.e.,

$$DQ^z = \frac{75 - 100}{15} = -\frac{5}{3} \tag{5}$$

Given $ASQ^z = -1.5$ and the corresponding DQ is 75 (Figure 2), the following relationship, without loss of generality, holds:

$$DQ^z = ASQ^z(x) \tag{6}$$

where x is the unknown factor for estimating DQ^z given ASQ^z. Given that when $ASQ^z = -3/2$ the corresponding $DQ^z = -5/3$ we have:

$$x = \frac{DQ^z}{ASQ^z} = \frac{-5/3}{-3/2} = \frac{10}{9} \tag{7}$$

Hence, our conversion factor from ASQ^z to DQ^z is given by $10/9$.

Age of Test Scaling Factor

Children may not, for various reasons, be administered the test corresponding to their biological age. Hence, to adjust for this when computing the final DQ^z we use the following adjustment factor.

$$Age^{adj} = \frac{Age^{test}}{Age^a} \tag{8}$$

where Age^{test} is the age at which the test is designed for, in months, and Age^a is the child's biological age, which may be adjusted if born pre-term.

Age Adjusted Developmental Quotient (DQ_{adj})

Using equation (3) and substituting in equation (6) for DQ^z, where $x = 10/9$ (equation 7), and our age adjustment factor (equation 8), our age adjusted DQ is estimated by:

$$\widehat{DQ}_{adj} = \left[100 + 15\left(\frac{10}{9}\right)ASQ^z\right]\left(\frac{Age^{test}}{Age^a}\right) \tag{9}$$

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Examples of Estimating the Developmental Quotient

This example assumes that $ASQ^z = -1.5$ and the $Age^{test} = Age^a = 6$ months. Hence, using this information in equation (9) we have:

$$\widehat{DQ}_{adj} = \left[100 + 15\left(\frac{10}{9}\right)\left(-\frac{3}{2}\right)\right]\left(\frac{6}{6}\right) = 100 + 15\left(-\frac{5}{3}\right) = 100 - (5)(5) = 75 \qquad (10)$$

Hence, $\widehat{DQ}_{adj} = 75$ and, by definition, $DD = 100 - \widehat{DQ}_{adj} = 25$, which equals the information provided in Figure 2. Our second example assumes that $ASQ^z = -1.5$ but that the $Age^{test} = 6$ months and differs from the Age^a of 12 months. Hence, using equation (9) we have:

$$\widehat{DQ}_{adj} = \left[100 + 15\left(\frac{10}{9}\right)\left(-\frac{3}{2}\right)\right]\left(\frac{6}{12}\right) = \left[100 + 15\left(-\frac{5}{3}\right)\right]\left(\frac{1}{2}\right) = 37.5 \qquad (11)$$

The DD is estimated as $100 - 37.5 = 62.5$. As you can see, using the conversion and age adjustment factors, that the result is a direct link from ASQ^z to the $\widehat{DQ}_{adj}$. If we assume $ASQ^z = -1.5$, $Age^{test} = 6$ months, and $Age^a = 12$ months then the result is adjusted to reflect they were given a test that was appropriate for a 6 month old child and they were 12 months old.

Age Adjusted Developmental Quotient Z-Score

Since our analysis uses DQ^z we substitute our age adjusted DQ equation 9 $(\widehat{DQ}_{adj})$ into equation (1) to estimate our analysis outcome $\widehat{DQ}_{adj}^z$ as:

$$\widehat{DQ}_{adj}^z = \frac{\widehat{DQ}_{adj} - \mu^{DQ}}{\sigma_{DQ}} \qquad (12)$$

and results in

$$\widehat{DQ}_{adj}^z = \frac{\left[\left(\mu^{DQ} + \sigma_{DQ}\left(\frac{10}{9}\right)ASQ^z\right)\left(\frac{Age^{test}}{Age^a}\right)\right] - \mu^{DQ}}{\sigma_{DQ}} \qquad (13)$$

References

[1] Filgueiras, A., Pires, P., Maissonette, S., & Landeira-Fernandez, J. (2013). Psychometric properties of the Brazilian-adapted version of the Ages and Stages Questionnaire in public child daycare centers. *Early Human Development*, 89(8), 561-576. doi:https://doi.org/10.1016/j.earlhumdev.2013.02.005