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

**$\text{ASQ}^z$ to $\text{DQ}^z$ Conversion Factor**

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

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

(5)

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

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

(6)

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

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

(7)

Hence, our conversion factor from $\text{ASQ}^z$ to $\text{DQ}^z$ 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 $\text{DQ}^z$ we use the following adjustment factor.

$$\text{Age}^{\text{adj}} = \frac{\text{Age}^{\text{test}}}{\text{Age}^a}$$

(8)

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

**Age Adjusted Developmental Quotient ($\text{DQ}_{\text{adj}}$)**

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

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

(9)
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:

$$\widehat{DQ}_{adj} = \left[100 + 15 \left(\frac{10}{9}\right) \left(-\frac{3}{2}\right)\right] \left(\frac{6}{6}\right) = 100 + 15 \left(-\frac{5}{3}\right) = 100 - (5)(5) = 75$$  \hspace{1cm} (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:

$$\widehat{DQ}_{adj} = \left[100 + 15 \left(\frac{10}{9}\right) \left(-\frac{3}{2}\right)\right] \left(\frac{6}{12}\right) = \left[100 + 15 \left(-\frac{5}{3}\right)\right] \left(\frac{1}{2}\right) = 37.5$$ \hspace{1cm} (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 $\widehat{DQ}^z_{adj}$ as:

$$\widehat{DQ}^z_{adj} = \frac{\widehat{DQ}_{adj} - \mu_{DQ}}{\sigma_{DQ}}$$ \hspace{1cm} (12)

and results in

$$\widehat{DQ}^z_{adj} = \frac{\left(\mu_{DQ} + \sigma_{DQ} \left(\frac{10}{9}\right) ASQ^z\right) \left(\frac{Age^{test}}{Age^a}\right) - \mu_{DQ}}{\sigma_{DQ}}$$ \hspace{1cm} (13)

References