Statistical Supplement

In order to allow for comparisons across multiple task parameters despite incompatible units of measurement (e.g. m/s, cm), raw task variables (task 'parameters') had to be standardized, i.e. converted to Z-scores. We additionally sought to summarize performance on robotic tasks using a metric that we refer to as the Task Score. This is a single value that provides an approximation of performance across all task parameters.

We generated Z-scores based on the performance of large cohorts of healthy control participants (without any known neurological impairments or other confounding factors), and accounted for the influence of age, sex, handedness, and robotic platform on performance. Box-Cox equations were used to normalize the distributions, followed by an iterated process of de-skewing and outlier removal. We defined outliers as datapoints with Z > |3.29|. Z-Scores that typify a "one-sided" impairment were additionally transformed so that impairment was always considered to be a higher value. Two examples of one-sided impairments with opposing impairment directions are a) the number of objects hit in the OH task, where fewer is always poorer performance on the task; and b) initial direction angle in VGR, in which greater values always represent poorer performance. We implemented this mathematically by creating "Zeta-scores" from the Z-scores:

$$Zeta = \sqrt{2} \cdot erfcinv\left(0.5 \cdot erfc\left(\frac{Z}{\sqrt{2}}\right)\right) \quad (1)$$

Here, *erfc* refers to the complementary error function and *erfcinv* refers to its inverse (implemented in Matlab R2018a as erfc and erfcinv functions, respectively). This transformation ensured that "good performance" was always represented by smaller values and "poor performance" was always represented by higher values. We did not transform 2-sided values, e.g. parameters describing lateralization in OH or OHA, in which values either very negative (i.e. strong leftward movement bias) or very positive (i.e. strong rightward movement bias) could equally indicate impairment. Next, the root sum-square (RSS)-distance was derived:

$$rssDistance = \sqrt{\sum_i {Z_i}^2 + \sum_j {Zeta_j}^2} \qquad (2)$$

This is effectively the Euclidean distance of all parameter Z-scores (and parameter Zeta-scores when necessary). The *rssDistance* was then converted to a Z-score using the standardization procedures employed during parameter Z-score calculation, described above. We called this value the "Z-Task Score". Finally, the one-sided Task Score was calculated:

$$Task\ Score = \sqrt{2} \cdot erfcinv\left(0.5 \cdot erfc\left(\frac{ZTaskScore}{\sqrt{2}}\right)\right) \qquad (3)$$

For further detail on robotic tasks and the calculation of standardized scores, please refer to the documentation available on www.kinarm.com.