

Improving Quality Assurance in Digital Cognitive Pre-Screening Through Single-Session Anomaly Detection

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What is the Methodological Issue Being Addressed? A key methodological issue in using brief digital cognitive assessments for pre-screening is session-level quality assurance. In remote or clinic-based settings, a single low score may reflect transient anomalous underperformance, for example due to distraction or disengagement, rather than true cognitive impairment. Without a way to identify these sessions, pre-screening decisions may be distorted through inappropriate inclusion or exclusion by misrepresenting an individual's cognitive status. We addressed this by developing a classifier to detect anomalous digital Digit Symbol Substitution (DSST) performance using detailed trial-level behavioural features derived from a large longitudinal dataset.

Introduction The 90-second digital DSST has potential value as a brief remote pre-screening tool, with task score significantly predicting cognitively normal versus mild cognitive impairment (MCI) status and performing comparably to longer cognitive assessments. DSST performance against age norms may also help group individuals by likely level of pathology risk. However, interpretation of a single-session score is limited by the possibility that an isolated low performance may be unrepresentative of true underlying cognition. Beyond total score alone, the digital DSST task contains rich trial-level behavioural data that may help identify such anomalous performances.

Methods Data were drawn from 23,004 US adults followed for up to 24 months, yielding 3.5 million DSST sessions. From low-level within-task signals such as response latency and drawing behaviour we extracted over 1,000 features from a single DSST session, capturing variability, timing irregularity, and within-session disruption. Anomalous sessions were identified from each participant's longitudinal performance by modelling expected performance and flagging sessions that fell significantly below this expected level. These labelled sessions were used to train an XGBoost classifier, which was then evaluated on its ability to detect anomalous first-session performance across norm-defined groups.

Results Model generalisability was assessed by testing how well the classifier translated to first-session anomalies defined at different normative cut-offs. Discrimination was strongest for the most impaired groups, with Receiver-operator curve (ROC) area under the curve (AUC) of 0.958 at the 5th percentile, 0.911 at the 15th percentile, and 0.849 at the 25th percentile, while remaining useful at less impaired thresholds, with ROC AUCs of 0.828 at the 30th percentile and 0.730 at the 50th percentile. Informative features were dominated by response-latency and drawing related features. In particular, the top-ranked feature, 'response latency top 3 share', captured whether a small number of trials disproportionately contributed to total response time, while prominent

drawing related features reflected the structure of within-trial pauses. These findings suggest that anomalous performance can be detected from timing irregularity within a single DSST session.

Conclusion A single brief digital DSST session contains sufficiently rich behavioural information to support anomaly detection beyond total score alone. Detecting anomalous low performances may improve confidence that low DSST scores used in remote pre-screening reflect underlying cognitive impairment rather than transient disruption.

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