Machine Learning on Drawing Behavior for Dementia Screening

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Introduction[1]

Dementia is a public health problem which is affecting millions of elderly worldwide. Many screening tests are available for early detection on the symptoms of dementia, but most of them are in paper-and-pencil form. The guidance and judgment on test performance are heavily relied on healthcare professionals, but the subjective evaluation always incurs human bias. With advancement of technology, screening tests can be digitalized into computing format, and performed in any portable devices. Geometric drawing is one of the common questions among the screening tools, and digital screening platforms can real-time capture the drawing behavior which directly reflects the brain response during the screening. We had developed a platform to capture the drawing behavior and invited participants with different levels of dementia to be screened with this digital test.

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Aim:

We applied machine learning to study the relationship of drawing behavioral data between participants with or without symptoms of dementia, and hypothesized that brain response time when drawing a simple figure can be digitalized for early detection of dementia.

Methods:

Patients diagnosed with moderate-to-severe stage of Alzheimer's disease (AD) were recruited from dementia clinics in Hong Kong. People without clinical symptoms of dementia were recruited from local community centers. Montreal Cognitive Assessment (MoCA) test was done in all subjects before screening with the digital screening test. AD patients were classified with MoCA<22, and healthy subjects were with MoCA≥22 as suggested by Tan etal. [1] All participants had to draw two interlocking pentagons using their fingers on the touch screen in a tablet with reference to a sample figure. The drawing processes were modelled by Markov chains of order m, with n states of two continuous variables - drawing velocity and drawing direction. To transit from one state to another, for continuous variable we need a transition function instead of transition matrix. Gaussian processes were employed to specify the set of transition functions as distributions. This maintained a probabilistic tractability for Bayesian inference. Together the resultant combination of models is coined Gaussian process Markov Chains (GPMC). To maximizing specificity and sensitivity, we determined an optimal cut-off by plotting a Receiver Operating Characteristic (ROC) curve. The performance of the drawing platform was compared to the human judgement with reference to the scoring standard in the traditional screening test, the Mini-Mental State Examination (MMSE). Confidence intervals were calculated using Clopper-Pearson exact method.

Results:

A total of 798 participates was recruited, and 519 (65.0%) of them were classified with AD. The average age of AD patients was 80.3 years (SD=6.5), and average MoCA scores of 14.6 (SD=4.8). The median drawing time of the interlocking pentagons was 17.5 seconds. In the 279 healthy subjects, the average age was 75.5 years (SD=7.7), and with average MoCA scores of 24.9 (SD=2.1). The median drawing time on the pentagons was 12.7 seconds. The digital drawing platform shows a good diagnostic performance on the patients with AD with sensitivity of 74.1% and specificity of 72.3%. The comparison with the traditional scoring method in MMSE was shown in Table 1.

Conclusion:

Drawing behavior can be real-time captured with digital platform and further analyzed by machine learning methods for early detection of dementia. Other behavioral tests on memory, attention, and executive functions can be further developed as a digital platform for centralized cognitive screening. Big data on real-time behavioral features will be an emerging area in digital health research.

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Table 1: Screening Performance of Different Screening Methods for Dementia

	MMSE's Scoring (95% CI)	Drawing platform (95% CI)
Sensitivity	68.8% (64.6%, 72.8%)	74.2% (70.2%, 77.9%)
Specificity	52.5% (45. 7%, 59.3%)	72.4% (66.8%, 77.6%)
Positive predictive value	77.4% (74.7%, 80.0%)	83.3% (80.4%, 85.9%)
Negative predictive value	41.5% (37.2%, 45.9%)	60.1% (56.2%, 64.0%)

Abbreviation: CI: confidence interval

Reference

[1] Tan JP, Li N, Gao J, Wang LN, Zhao YM, Yu BC, et al. Optimal cutoff scores for dementia and mild cognitive impairment of the Montreal Cognitive Assessment among elderly and oldest-old Chinese population. Journal of Alzheimer's disease : JAD. 2015;43(4):1403-12.