Early Diagnosis of Alzheimer's Dementia with the Artificial Intelligence based Integrated Cognitive Assessment

Hadi Modarres[1], Vahid Reza Khazaie[2], Mohammad Ghorbani[2], Amir Mohammad Ghoreyshi[2], Alireza AkhavanPour[2], Reza Ebrahimpour[2], Zahra Vahabi[3], Chris Kalafatis[1], Seyed-Mahdi Khaligh-Razavi[1,4]*

(1) Cognetivity Ltd, London, United Kingdom,
(2) Shahid Rajaee Teacher Training University, Tehran, Iran
(3) Department of Geriatric Medicine, Ziaeian Hospital, Tehran, Iran
(4) Royan Institute, Tehran, Iran

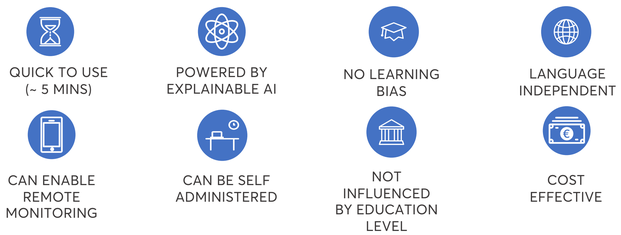
*correspondence to Seyed@Cognetivity.com

Background Science

The Integrated Cognitive Assessment (ICA) test is based on humans' strong reaction to animal stimuli, and the ability of a healthy brain to process images of animals in less than 200ms [1-3].

ICA is a rapid animal/non-animal visual categorization test, engaging brain areas affected in pre-symptomatic stages of Alzheimer's and detecting subtle impairments in information processing speed, aiming to detect the earliest signs of disease before the onset of memory symptoms.

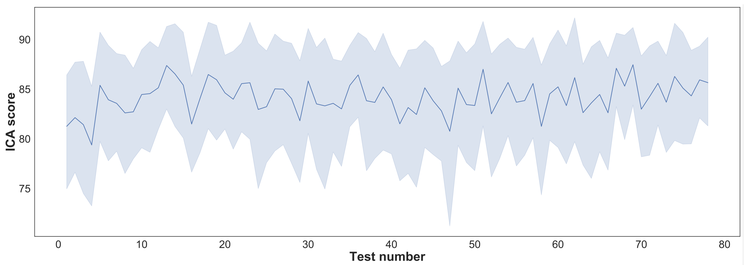
Attributes of the ICA test



The ICA gives an objective, highly sensitive measure of cognitive function. The test has a lack of floor and ceiling effects, does not require a study partner and provides automated scoring, using AI to improve classification accuracy. The ICA offers significant clinical benefits in identification of MCI and AD in specialist clinical settings, in primary care and in remote cognitive monitoring.

The ICA can also be used as an effective recruitment screening tool for clinical and pharmaceutical trials and as an outcome measure/endpoint that can be taken with high frequency to provide superior resolution of treatment efficacy.

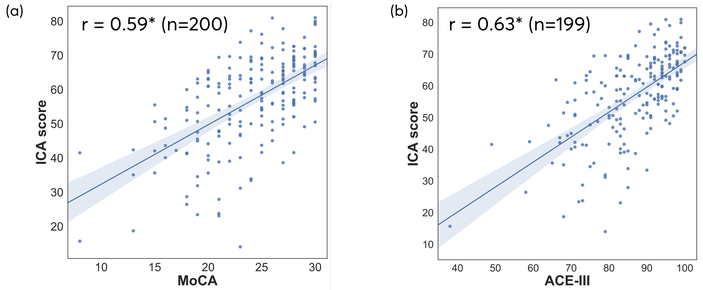
ICA shows no significant practice effect and can be used for remote monitoring



A mobile phone version of the ICA was provided to 12 healthy participants (age 26 – 73) who took 78 tests on an approximately daily basis (936 tests in total). The mean of their scores, with the 95% confidence interval is shown above. The ANOVA one way p-value obtained was 0.99, showing no significant practice effect.

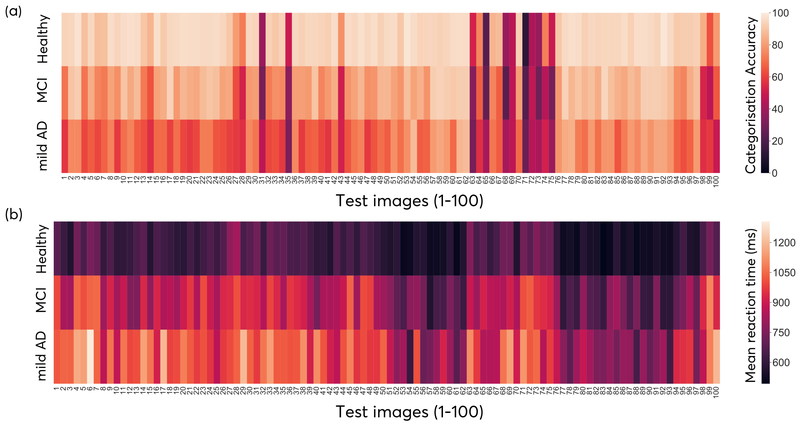
Furthermore the ICA test was taken by participants remotely and was self administered, providing evidence for the use of the ICA as a tool for remote monitoring.

ICA correlation cognitive tests



The ICA demonstrates convergent validity with MoCA and ACE, and has been shown to have a strong correlation with severity of neural damage as measured by NfL biomarker[4].

ICA data features for classification

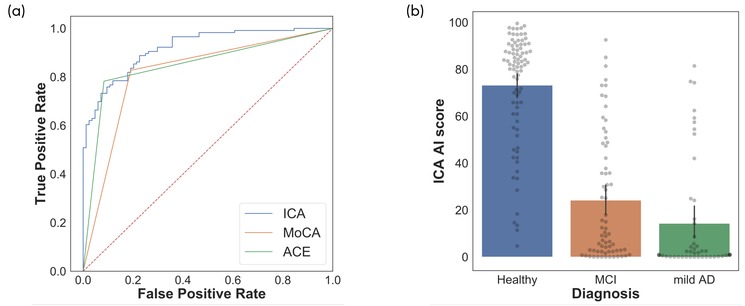


The raw data from the ICA test (categorisation accuracy and reaction time) has been visualised to show how healthy and impaired participants perform differently on the test. In figure (a) the the mean categorisation accuracy, and in (b) the mean reaction time in milliseconds, for the three diagnosis arms are shown.

This showcases the different signature patterns between the groups and forms a rich dataset to train machine learning models to distinguish between the different arms.

Features from the ICA test, alongside demographic data was used to train a logistic regression machine learning model. We also investigated the use of a deep (50 layers) neural network to extract informative features from the ICA test response patterns. However since the performance between these models was similar, we opted for the simpler logistic regression model due to its increased explainability, as will be explained later.

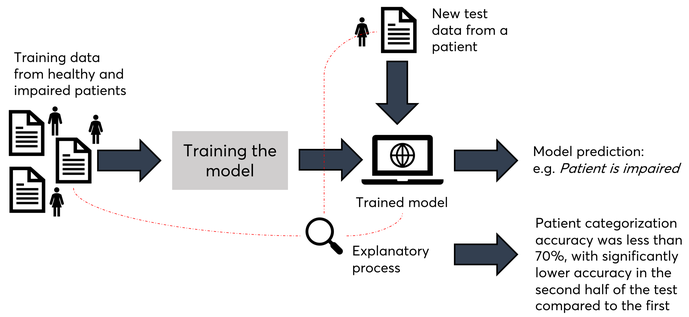
ICA accuracy in detecting cognitive impairment



(a) The ICA was able to discriminate between healthy (n=84) and impaired participants (MCI n= 68 , mild AD n= 48) with a receiver operating curve AUC of 0.92, compared to 0.82 for MoCA, and 0.84 for ACE. Model testing was performed by leave one out cross validation on the 200 participants

(b) A bar plot showing the difference in ICA AI score between the different diagnoses. The mean and 95% confidence interval lines are shown. Each dot represents a single prediction from the machine learning model. The Cohen's D effect size between healthy and MCI/mild AD is 2.1.

Explainable AI



Utilising a logistic regression model allows the importance of individual features to the model's prediction be realised. Therefore a model's prediction can be traced back to identify the reasons behind the prediction, providing interpretable and explainable results for the clinician or health care professional.

Publications

(1) Khaligh-Razavi, S.M. *et al.* Integrated Cognitive Assessment: Speed and Accuracy of Visual Processing as a Reliable Proxy to Cognitive Performance. *Sci. Rep.* 9, 1102 (2019).

(2) Khaligh-Razavi, S.M., Cichy, R.M., Pantazis, D., & Oliva, A. (2018). Tracking the spatiotemporal neural dynamics of object properties in the human brain. Journal of Cognitive Neuroscience, 30(11), 1559-1576.

(3) Mirzaei, A., Khaligh-Razavi, S.M., Ghodrati, M., Zabbah, S., & Ebrahimpour, R. (2013). Predicting the human reaction time based on natural image statistics in a rapid categorization task. Vision research, 81, 36-44.

(4) Khaligh-Razavi, S.-M., Sadeghi, M., Khanbagi, M., Kalafatis, C. & Nabavi, S. M. A self-administered, artificial intelligence (AI) platform for cognitive assessment in multiple sclerosis (MS). BMC Neurol. 20, 193 (2020).