Facial Emotion Analysis for Early and Differential Diagnosis of Neurodegenerative Disorders: A Neuropsychological Application of AI

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BACKGROUND

Dementia, including Alzheimer's disease (AD), shows not only progressive cognitive decline but also early changes in emotional processing and facial expressivity caused by limbic–prefrontal circuit dysfunction [1]. Such blunted or atypical affective responses are clinically recognized but seldom measured or used diagnostically [2].

We evaluated AI-based facial emotion analysis as a non-invasive tool to capture these alterations, testing its usefulness for early detection of mild cognitive impairment (MCI) and for differentiating AD from non-AD dementias.

METHODS

We recruited 64 participants from the Aging Brain and Memory Clinic of the University of Turin: 28 healthy controls (HC), 26 with MCI, and 10 with overt dementia of mixed etiologies. All underwent comprehensive diagnostic work-up including neurological examination, neuropsychological testing, MRI, 18F-FDG PET, and CSF biomarkers (A/T/N framework) for etiological classification. Groups were comparable for age and education. Cognitive screening reflected expected severity: HC MMSE 29.18 ± 1.14; MCI 25.69 ± 3.75; dementia 17.25 ± 6.73. Emotional responsiveness was assessed with an 8-minute audiovisual paradigm using IAPS/IADS-2 [3] stimuli selected to cover a wide range of valence–arousal states while ensuring safety and tolerability. Facial reactions were recorded in real time with a high-resolution webcam synchronized to stimulus presentation. The experimental setup is shown in Figure 1, depicting audiovisual stimulation, webcam-based recording, and AI analysis. Frames were processed using a SENet-based CNN pre-trained on AffectNet [4] to extract continuous valence and arousal trajectories. These features were classified with k-nearest neighbors (KNN), support vector machine (SVM), and logistic regression (LR), with performance estimated through nested cross-validation to reduce overfitting.

RESULTS

Facial emotion analysis differentiated patients from controls. Pooling all cognitively impaired participants against HC, the KNN classifier achieved 73.6 % ± 0.10 accuracy (F1 = 0.72), outperforming SVM and LR (≈ 62 %). The best performance was obtained for MCI vs HC: 76.0 % ± 0.04 accuracy (F1 = 0.75), showing that emotion dysregulation is detectable at the prodromal stage. For dementia vs HC, accuracy remained ≈ 73 %, but F1 scores were lower (0.42–0.49) due to the small, heterogeneous dementia group. The system also distinguished AD from non-AD dementias with 75.4 % ± 0.13 accuracy (F1 = 0.75).

Figure 2 summarizes classification performance, highlighting the high accuracy in MCI.

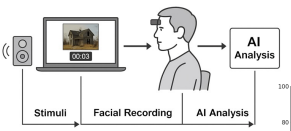

Figure 1. *Experimental setup for facial emotion analysis.*

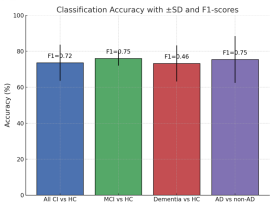

Figure 2. *Classification performance across diagnostic comparisons.*

CONCLUSION

Facial emotion dysregulation proves to be an early, clinically relevant marker of neurodegeneration. Its performance in MCI supports early case detection, and the ability to distinguish AD from non-AD dementias adds value for differential diagnosis. AI-based facial emotion analysis is objective, reproducible, and non-invasive, complementing traditional neuropsychological assessment. Future studies in larger multicenter cohorts and longitudinal designs will help establish its clinical utility.

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