Introduction of Stroop-Based Cognitive Assessment for Neurodegenerative Disorders (SCAN-D)

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Key highlights:

- Stroop-based screening detects executive-attention deficits that may precede memory decline in MCI and early Alzheimer's disease.
- Digital and VR-adapted Stroop tasks demonstrate high diagnostic accuracy and scalable clinical implementation potential.
- Multimodal integration with EEG and fNIRS enhances mechanistic understanding of compensatory prefrontal activation in early neurodegeneration.

Dementia prevalence continues to rise globally, reinforcing the urgency of early detection and preventive intervention. The 2024 update of the *Lancet* Commission estimates that nearly half of dementia cases may be preventable through targeted management of modifiable risk factors across the life course (Livingston et al., 2024). Similarly, recent national guidance calls for accelerated development of scalable diagnostic tools capable of identifying cognitive decline earlier and more accurately in primary-care settings (National Institute on Aging [NIA], 2025). Despite this momentum, most widely used cognitive screening tools remain predominantly memory-centric. However, growing evidence suggests that executive functions—particularly selective attention, inhibitory control, and interference resolution—often decline as early as or earlier than episodic memory in neurodegenerative disease (Idowu et al., 2024; Parris et al., 2021). This discrepancy highlights the need to broaden screening frameworks. Stroop-Based Cognitive Assessment for Neurodegenerative Disorders (SCAN-D) proposes a structured integration of interference-based measures to complement traditional memory screens.

The Stroop task, originally introduced by Stroop (1935), remains one of the most robust paradigms for assessing cognitive interference. Participants are instructed to name the ink color of a word while inhibiting the automatic tendency to read the word itself. For example, the word "RED" printed in blue ink requires the response "blue." This conflict between automatic and task-relevant responses probes inhibitory control, selective attention, conflict monitoring, and cognitive flexibility (Parris et al., 2021). Experimental lifespan research demonstrates that Stroop interference increases with age, reflecting gradual reductions in inhibitory efficiency (Forte et al., 2024). These executive changes may precede clinically significant memory impairment, suggesting that interference-based measures could detect earlier cognitive vulnerability.

Neuroimaging research further supports the mechanistic relevance of the Stroop paradigm. Functional studies consistently implicate the anterior cingulate cortex in conflict monitoring and the dorsolateral and ventrolateral prefrontal cortices in top-down control during Stroop performance (Cipriani et al., 2025). In individuals with mild cognitive impairment (MCI), functional near-infrared spectroscopy (fNIRS) studies reveal increased prefrontal activation during Stroop tasks, interpreted as compensatory neural recruitment (Fan et al., 2025). This compensatory pattern may sustain behavioral accuracy despite prolonged reaction times. However, as pathology progresses, compensatory mechanisms may fail, leading to declines in both efficiency and performance (Liampas et al., 2024). Thus, Stroop-based assessment provides insight not only into behavioral interference but also into the evolving neural dynamics of compensation and dysfunction in early neurodegeneration.

Recent technological innovations have expanded Stroop assessment beyond traditional paper-and-pencil formats. Digital and virtual reality (VR) adaptations improve ecological validity while enabling automated timing and scoring (Cornacchia et al., 2025). For instance, a VR-based Stroop paradigm demonstrated exceptionally high discrimination between individuals with MCI and healthy controls, with area-under-the-curve (AUC) values approaching 0.98, outperforming conventional memory screens such as the MoCA-K (Park, 2025). Additionally, reaction-time slowing under increased cognitive load reliably differentiates MCI from normal aging (Zhu et al., 2025). These findings underscore the sensitivity of interference-based tasks to subtle executive changes that may precede overt memory decline.

Systematic reviews integrating psychophysiological and imaging evidence further confirm the diagnostic utility of Stroop paradigms. Cipriani et al. (2025) conclude that interference-based tasks remain highly effective in distinguishing healthy aging, MCI, and Alzheimer's disease (AD), particularly due to prefrontal compensatory dynamics observable through EEG, ERP, fNIRS, and fMRI. ERP research also identifies distinct biosignatures associated with early cognitive decline, suggesting that Stroop-evoked neural responses may serve as longitudinal biomarkers (Meghdadi et al., 2024). Importantly, these neural signatures may vary across dementia subtypes, offering potential for differential diagnosis when behavioral and physiological measures are combined (Liampas et al., 2024).

Despite this growing evidence base, Stroop tasks are rarely embedded within routine clinical workflows. Several barriers contribute to this gap. First, memory screens remain more familiar to clinicians and are perceived as simpler to administer. Second, variability in task design—differences in timing, stimulus presentation, scoring algorithms, and normative references—limits standardization across settings (Idowu et al., 2024). Third, digital tools raise concerns regarding training requirements, cost, and data security (Cornacchia et al., 2025). Finally, cultural and linguistic variability influences Stroop performance, emphasizing the need for cross-cultural norms aligned with global prevention frameworks (Livingston et al., 2024).

SCAN-D addresses these implementation challenges by positioning Stroop-based measures as complementary rather than replacement tools. Executive-attention assessment can be integrated into stepped-care models following initial memory screening to guide referral and further evaluation (NIA, 2025). Several advantages support this approach. First, Stroop indices detect early interference-control deficits and prefrontal inefficiency even when memory scores remain within normal limits (Fan et al., 2025). Second, digital and VR platforms enhance scalability, facilitating remote or community-based screening while preserving measurement precision (Park, 2025). Third, multimodal integration with EEG or fNIRS provides mechanistic insights into compensatory activation versus neural failure across disease progression (Meghdadi et al., 2024; Liampas et al., 2024). Finally, expanding screening beyond memory aligns with contemporary dementia-prevention frameworks emphasizing comprehensive cognitive evaluation (Livingston et al., 2024).

Future research priorities are clear. First, consensus parameters must be established regarding optimal task duration, interference scoring, and cutoff thresholds. Executive-function reviews emphasize the importance of standardized protocols to improve clinical interpretability (Idowu et al., 2024). Second, cross-cultural validation is essential to develop normative data across languages and education levels. Third, longitudinal studies should evaluate whether Stroop-based measures predict conversion from normal aging to MCI and from MCI to dementia, particularly when combined with physiological markers (Meghdadi et al., 2024). Fourth, telehealth validation studies are needed to assess usability, engagement, and reliability in remote settings (Cornacchia et al., 2025). Finally, research should further examine biomarker integration, distinguishing compensatory activation from progressive neural failure using fNIRS and ERP indicators (Fan et al., 2025; Liampas et al., 2024).

From a psychogeriatric standpoint, Stroop-based assessment offers both theoretical coherence and practical feasibility. The paradigm is grounded in well-established cognitive science and directly maps onto prefrontal networks vulnerable in early neurodegeneration. At the same time, it remains brief, low-cost, and adaptable to digital platforms. By integrating executive-attention measures into routine screening, clinicians may identify at-risk individuals earlier, initiate preventive strategies sooner, and monitor progression more sensitively.

In conclusion, Stroop-Based Cognitive Assessment for Neurodegenerative Disorders (SCAN-D) represents a mechanistically informed expansion of current dementia screening practices. Converging evidence from behavioral, digital, and neurophysiological studies demonstrates high sensitivity to MCI and early AD, particularly in detecting executive-attention impairments that often precede measurable episodic-memory decline (Cipriani et al., 2025; Fan et al., 2025). Broader implementation will require standardization, cross-cultural validation, and integration into clinical pathways. Nevertheless, the convergence of cognitive theory, neural evidence, and digital innovation positions Stroop-based screening as a compelling complement to memory-centric tools in the early detection of neurodegenerative disorders.

For further reading:

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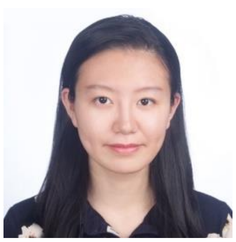
As an associate professor, Dr. Lin Wang focuses on the design, implementation, and evaluation of culturally responsive learning and behavior-change environments that promote sustainable health and educational outcomes.



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