



Intelligent Support Systems for Individuals at Risk of Neurodegenerative Diseases

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The central paradox of cognitive-support AI: those who need it most can afford it least. Individuals experiencing neurocognitive decline are asked to engage the very capacities a system is designed to compensate. The proposed TRACE Model resolves this contradiction by inverting the burden — the architecture adapts, the user simply lives.

Background

- Early-stage neurodegeneration disrupts attentional control, episodic encoding, and executive planning.
- Dominant AI systems optimize retrieval latency and fluency, not cognitive load calibration.
- Objective: architect AI to sustain neurocognitive safety across fluctuating cognitive states.

Methods

- Design science research (DSR) paradigm; AI cognitive-support prototype targeting MCI and at-risk populations.
- Multi-stage inquiry: semi-structured need-finding, co-design, and iterative prototyping cycles.
- Clinician-validated evaluation: extraneous load, emotional attunement, and perceived clinical utility.

Conclusion

- Accuracy and fluency are necessary but insufficient for neurologically vulnerable populations.
- TRACE operationalizes teleological coherence: affordances aligned to autonomy and stability.
- Theory-grounded blueprint for neurodegenerative risk management and equitable digital health.

Need-finding

→

Co-design

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Prototyping

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Evaluation

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TRACE Model

Results: From Neurocognitive Vulnerability to Design Principle

Need-finding interviews (n=18; MCI and at-risk status) surfaced five recurring neurocognitive vulnerability themes, each mapped to a TRACE design principle.

Cognitive Demand

“By the time I figure out how to use it, I’ve already lost the thread.”

Trust and Comprehension

“How am I supposed to know if it’s right when I can’t always trust my own judgment?”

Temporal Continuity

“Every time I open it, I have to start over; I can’t remember what I did last time.”

Emotional Regulation

“Seeing my scores go down doesn’t help me; it just makes everything feel worse.”

Agency and Initiation

“The days I need it most are the days I forget it exists.”

1. Adaptive Modulation

2. Contextual Assemblies

3. Temporal Awareness

4. Relevance Integration

5. Experiential Rendering

Your Dashboard
Last assessment Jun 12, 2026

OVERALL **Medium** 1.9 ASSESSMENTS 5 TREND Stable LAST 5

Risk Assessment
Your responses indicate some emerging difficulties. Consider discussing these changes with a healthcare provider.
Overall score: 19 / 25 32 of 36 questions scored

Areas of Concern 1
Memory 2.6 / 5

Areas to Monitor 2
Attention/Working Memory 2.3 / 5
Planning/Keeping Track 2.1 / 5

Areas to Maintain 3
Visuospatial/Navigation 1.2 / 5
Communication 1.4 / 5
Daily Living 1.5 / 5

Progression Trend
Lower scores are better. The threshold line at 2.5 separates medium from high risk.
5 months

Top Recommendations
Sample action items your AI companion would generate based on your responses. 7 active

- COGNITIVE TRAINING** (Jun 24): Spend 15 minutes/day on structured memory exercises (dual n-back or spaced-recall). Consistency matters more than duration.
- EXERCISE** (Jun 23): Aim for 150 min/week of moderate aerobic activity — brisk walking counts. Aerobic exercise is linked to improved hippocampal volume.
- DIETARY** (Jun 20): Shift toward a MIND-diet pattern: leafy greens daily, berries 2x/week, nuts, olive oil, and fish weekly. Limit ultra-processed foods.

MORE SUGGESTIONS

- HEALTH MANAGEMENT** (Jun 18): Schedule a check-up for blood pressure, A1c, and lipid panel. Cardiovascular health is a top modifiable factor for cognitive decline.
- SOCIAL** (Jun 15): Book one meaningful social interaction per week — call, coffee, or shared hobby. Social engagement is protective against decline.
- RESEARCH SUMMARY** (Jun 13): Read a recent PubMed summary on the MIND diet and cognitive decline. Evidence-based dietary patterns are consistently linked to slower cognitive aging.
- DOCTOR VISIT** (Jun 10): Prepare a visit summary for your clinician: overall score 19 (medium risk). Memory flagged as an area of concern, and ask whether a memory screening is appropriate.

Assessment History
A record of prior assessments Alex has completed.

- Jun 12, 2026: Overall score 19 / 25 (Medium Risk)
- May 05, 2026: Overall score 20 / 25 (Medium Risk)

Next steps
Demo actions available to logged-in users.

- Chat**: Talk with Neurata
- Perform new analysis**: Retake the assessment

Design Solution: Dashboard Prototype

The TRACE Architecture

Principle in order of Importance	Design Recommendations	Significance · Professional Care	Significance · Patients
1 Adaptive Modulation <i>Dynamic neurocognitive load regulation</i>	- Adaptive complexity modulation via real-time load signals - Load-aware turn-taking cadence and interruptibility thresholds	- Surfaces cognitive fluctuation phenotypes for individualized care planning - Reduces triage and intake assessment overhead	- Attenuates extraneous load during diminished-capacity states - Preserves response autonomy and interaction agency
2 Contextual Assemblies <i>Cue-proximal knowledge schema activation</i>	- Cue-triggered modular schema retrieval - Just-in-time scaffolding and risk-proximal guidance injection	- Delivers protocol-aligned guidance at point of care - Mitigates misinformation risk and knowledge gap propagation	- Delivers situated, cognitively proximal prompts - Suppresses irrelevant informational and environmental noise
3 Temporal Awareness <i>Temporal trajectory and drift detection</i>	- Longitudinal baseline-drift detection with anomaly flagging - Episodic memory anchor insertion and session-state restoration	- Generates objective longitudinal cognitive trajectory signals - Enables pre-clinical detection and early-decline screening	- Maintains cross-session contextual continuity - Compensates for episodic encoding and retrieval deficits
4 Relevance Integration <i>Cross-modal signal fusion and prioritization</i>	- Cross-modal data fusion with salience-weighted synthesis - Redundancy suppression and provenance-aware summarization	- Produces consolidated, actionable cross-domain clinical summaries - Informs shared decision-making and family psychoeducation	- Integrates fragmented self-management data into a unified interface - Reduces information retrieval and navigation burden
5 Experiential Rendering <i>Dignity-calibrated representational output</i>	- Affect-calibrated plain-language synthesis engine - Dignity-preserving, alarm-attenuating risk communication framing	- Enhances medical instruction comprehension and retention - Supports adherence monitoring and care-plan reinforcement	- Reduces burden of probabilistic risk interpretation - Sustains emotional regulation, security, and self-efficacy

Practical Recommendations · System Designers

- Deploy real-time cognitive load estimators (error rate, response latency, abandonment signals) as adaptive interaction complexity controllers.
- Implement persistent session-state graphs restoring neurocognitive context across asynchronous and interrupted interaction episodes.
- Architect HIPAA-compliant longitudinal pipelines discriminating intra-session fluctuation from inter-session cognitive drift trajectories.

Practical Recommendations · Clinical Care Providers

- Interpret AI-generated risk indices as longitudinal trajectory indicators, not cross-sectional diagnostic thresholds.
- Deploy domain-level cognitive dashboards as structured pre-encounter screening instruments to prioritize clinical inquiry.
- Calibrate intervention timing to system-detected baseline-drift anomalies rather than fixed appointment intervals or calendar schedules.

Call for Collaboration

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