

RESEARCH PLAN

SoundKraft: A Gamified, Sensory-Adaptive Screening System for Geriatric Cognitive Impairment

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1 Rationale

Cognitive decline, particularly Mild Cognitive Impairment (MCI), is a growing public health challenge with the aging global population. In India, where family structures rely heavily on elders, timely detection is essential to preserve their quality of life and independence. However, traditional cognitive screening tools like the MMSE and MoCA have limited accessibility for seniors with sensory impairments, low literacy, or diverse linguistic backgrounds, as they were designed for literate, English-speaking populations and require manual dexterity for the tasks. SoundKraft is developed to bridge these gaps through a gamified, sensory-adaptive cognitive assessment platform that is engaging, inclusive, and culturally adaptable. By detecting early signs of cognitive decline, it enables timely interventions that can significantly improve long-term cognitive health and quality of life.

2 Research Question

- How effectively can SoundKraft, a gamified and sensory-adaptive cognitive screening tool, detect cognitive impairment in elderly populations when compared to MoCA?

3 Hypothesis

A game-based, multimodal, sensory-adaptive screening system will demonstrate:

- Strong correlation with MoCA in detecting cognitive impairment.
- Higher engagement and accessibility for seniors with sensory impairments and low literacy.
- Increased sensitivity for detecting early-stage cognitive decline.

4 Engineering Goal

Deliver an accessible, and engaging cognitive assessment tool for geriatric individuals, offering comprehensive coverage, localization (languages), and actionable insights tailored to diverse populations, including those with age-related sensory needs.

5 Expected Outcomes

- Validation of SoundKraft's effectiveness against MoCA.
- High correlation with MoCA scores $r \geq 0.8$.
- Greater ease-of-use and engagement, particularly for sensory-impaired and low-literacy participants.
- Identification of specific cognitive domains (e.g., memory, attention) most affected in cognitively impaired seniors

6 Procedures

6.1 Participants

- Target population: Seniors between the age group 60-90
- Inclusion: Community-dwelling seniors, varying literacy levels, with/without sensory impairments.
- Exclusion: Individuals with severe psychiatric or neurological disorders, extreme comorbidities
- Recruitment: Community centers, senior living facilities, outpatient clinics.

6.2 Study Design

- Dual-cohort process:
 - Training Cohort: Used to calibrate SoundKraft scoring.
 - Testing Cohort: Independent participants for validating SoundKraft's performance.
- Balanced representation across literacy and sensory profiles.

6.3 Cognitive Assessments

- Each participant completes standard MoCA and SoundKraft
- MoCA administration is done as a part of this project to cross-validate the efficacy of SoundKraft and determine the threshold levels for varying levels of cognitive abilities.
 - The data utilized in our study is not derived from any publicly available sources. It is gathered firsthand through direct administration of the MoCA assessment by our mentor, Ms. Kavita Gadade, who has filled the Qualified Scientist Form. Prior to conducting the assessment, informed consent from each participant or their legal guardian is secured, in full adherence to ethical research standards. Additionally, we will be carrying the signed consent forms and all relevant documentation with us to ISEF.
- SoundKraft has the following game based activities:
 - EchoMatch - Recall the sequence of shapes/ sounds
 - PicChime- Recall the sequence of images
 - StoryWeaver- Listen short stories and give answers
 - LogicLink- Solve analogies by identifying connections
 - QuickAudio- Tap on an object with associated musical note
 - BlockMorph- Rotate on-screen blocks to match orientation
 - ChainReaction- Determine what action led to a specific result.
 - QuickTap- Tap the second a particular icon shows up
 - NumberSort - Arrange notes of currency in ascending order
 - SpotTheDifference - What changed between two images

- Personal Quiz - Answer questions based on initial data
 - EyeGaze - Follow the moving object on screen
- SoundKraft assesses six cognitive domains using the above activities:
 - Memory (visual and auditory recall)
 - Attention (rapid matching games)
 - Language Skills (image description)
 - Executive Function (pattern solving)
 - Visuospatial Ability (rotation puzzles)
 - Orientation (logic sequences)

6.4 Sensory-Adaptation in SoundKraft

- Text-to-speech prompts
- Audio-guided interactions to support low-literacy users
- Blink input

6.5 Scoring Methodology

- Scores are computed using Analytic Hierarchy Process (AHP), ensuring domain-specific weightages.
- Time based scores and accuracy scores are both considered while calculating an overall cognitive score
- Scores are normalized to the same scale as MoCA for interpretability.

6.6 Validation Process

- K-fold cross-validation (k=5) applied within the training cohort to fine-tune domain weightages.
- Test-retest reliability assessed by re-evaluating a subset after a brief interval.
- Scores analyzed for correlation with MoCA (Pearson's r) and agreement (Bland-Altman plot).

7 Protection of Privacy and Informed Consent Process

7.1 Privacy Protection

- All personal data collected during the study will be handled in strict accordance with established ethical research guidelines. Each participant will be assigned a unique identification code, and any personally identifiable information such as names and contact details will be stored separately from cognitive performance data.

- Performance data will be stored in anonymized form, with all identifying information removed before analysis. All data will be securely stored on password-protected files. Any publications, presentations, or reports derived from this study will present results in aggregate form, ensuring no participant can be individually identified.

7.2 Informed Consent Process

- The informed consent process will ensure participants fully understand the study's purpose, procedures, and any potential risks or benefits
- Each participant (or their caregiver if necessary) will receive a clear explanation of the study in their preferred language.
- Participants will have the opportunity to ask questions and seek clarifications before signing the consent form.
- The consent form will detail the purpose of the study, what participation entails, privacy protections, voluntary nature of participation, and the right to withdraw at any time without consequence.

8 Risk Assessment

- Minimal risk: All tasks are software-based and non-invasive.
- Participants may withdraw at any time.
- Test environment will be safe and familiar (e.g., community centers).

9 Data Analysis

- Sensitivity and specificity calculated using Receiver Operating Characteristic (ROC) curves.
- Subgroup analysis.
- Domain-specific performance (e.g., memory vs attention) analyzed to understand domain vulnerabilities in early MCI.

10 Bibliography

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