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UTILIZING LARGE LANGUAGE MODELS FOR OPTIMIZING SOUND SELECTION IN DEMENTIA CARE ENVIRONMENTS

Arezoo Talebzadeh[1*]

[1] Department of Information Technology - Ghent University.
Technologiepark 126, 9052, Ghent, Belgium

ABSTRACT

The effect of soundscape on people with dementia has been studied, with established links between acoustic environments and Behavioral and Psychological Symptoms of Dementia. Previous research has demonstrated promising results in using soundscape augmentation for dementia care interventions. However, selecting appropriate sound segments remains challenging due to the heterogeneous nature of dementia and varying individual needs. This study explores the innovative application of Large Language Models (LLMs) in selecting appropriate sound segments for soundscape augmentation. By analyzing responses from Claude 3.5 and GPT-4 to systematically designed prompts, the potential to recommend suitable sound segments based on the specific auditory deficits associated with different types of dementia was investigated. The LLMs were provided with semantic complexity ratings and affective information of pre-labelled sound segments and then tasked with matching appropriate sounds to various dementia types. Results demonstrate LLMs' capability to consider multiple factors, including semantic complexity, emotional impact, and specific auditory processing challenges when making recommendations. Key findings indicate that LLMs can effectively differentiate between suitable sound segments for various dementia types. This research suggests potential benefits in using AI-assisted sound selection to enhance personalized soundscape design in dementia care while acknowledging the importance of human oversight and individual patient preferences.

*Corresponding author: arezoo.talebzadeh@ugent.be

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1. INTRODUCTION

The effect of soundscape on people with dementia has been studied [1-3], with established links between acoustic environments and Behavioral and Psychological Symptoms of Dementia [4]. Previous research has demonstrated promising results in using soundscape augmentation for dementia care interventions [5]. However, selecting appropriate sound segments remains challenging due to the heterogeneous nature of dementia and varying individual needs (Talebzadeh, Botteldooren et al., 2023). Recently, there has been an interest in using large language models (LLMs) in soundscape studies. Hou et al. used LLM for soundscape captioning, identifying sound sources, and predicting annoyance [7-8].

Selecting suitable sound segments for soundscape augmentation is challenging as human bias and prejudice may unknowingly play a role. LLMs and Generative Pre-Trained transformers (GPT) have shown promising results in minimizing bias when prompted correctly and monitored.

This study aims to use LLMs to select suitable sounds for soundscape augmentation in dementia care settings based on specific subtypes of dementia, the auditory symptoms and deficits related to each type and the appropriate sound segment based on theoretical frameworks. To examine the possibility of LLMs as a tool to help select suitable sound, Claude 3.5 and Chat GPT 4o were prompted, and results were analyzed for homogeneity and reliability.

2. METHODOLOGY

2.1 Experimental Design

This study employed a methodological approach to evaluate the potential of LLMs in selecting appropriate sound segments for people with dementia. Claude 3.5 and GPT-4o were utilized to analyze and recommend suitable sound segments based on different types of dementia and their associated auditory deficit. The study followed a three-phase process:

1. Initial general prompting to access LLM understanding of sound selection for dementia
2. Specific prompts addressing specific dementia types and their auditory deficit
3. Complex scenario-based prompts with detailed sound segment information to design a soundscape

2.2 Prompt Engineering

To evaluate the LLM's capabilities, a series of specific prompts were developed from general to specific, using four elements: instruction, context, input data, and output indicator [9].

1. **General question**: "How can LLM be used to enhance sound segment selection for people with dementia when designing soundscapes?"
2. **Specific segment selection**: "I need your help locating the most suitable sound segments to enhance the auditory environment for individuals with dementia."
3. **Auditory deficit inquiry**: "What are the auditory deficits of each type of dementia?"
4. **Scenario**-based prompts: Two specific scenarios were presented:
    a. **Scenario A:** Sound selection for frontotemporal dementia in long-term care home
    b. **Scenario B:** Comparison of sound selection for Alzheimer's disease (AD) vs. frontotemporal dementia (FTD)

2.3 Sound Segment Analysis

The sound segment labelling was conducted online through online Audio Captioning: https://huggingface.co/spaces/wsntxxn/efficient_audio_captioning

The program labelled a comprehensive set of sound segments from previous research [6]. Each segment was then characterized by:

1. Identification number (e.g., W0004, W00026)
2. Audio caption (e.g., "rain falling on a surface", " a crowd of people are talking")
3. Semantic complexity rating (low, moderate and high)

Recognizing the inability of LLMs to directly process audio files (at the time of experience), the pre-labelled sound segments were utilized for the study. LLMs were provided with this information to make recommendations.

2.4 Evaluation Framework

LLM responses were evaluated based on:

1. Understanding of dementia-specific auditory deficits
2. Appropriate matching of sound segments to dementia type
3. Consistency of recommendation across models

3. RESULTS

3.1 LLM Understanding of Sound Selection for Dementia

Both LLMs demonstrated a sophisticated understanding of using sound segments for dementia interventions. In response to general prompts, both models provided structured approaches:

GPT-4o outlined a six-stage process:

1. Personalized Sound Recommendations
2. Tailoring to Specific Auditory Deficits
3. Adapting to Cognitive and Emotional States
4. Contextual Sound Placement
5. Data-Driven Sound Optimization
6. Combining with Assistive Technologies

Claude 3.5 proposed an eight-step framework:

1. Content analysis
2. Personalization
3. Emotional response prediction
4. Narrative generation
5. Temporal sequencing
6. Interaction analysis
7. Metadata enhancement
8. Contextual adaptation

3.2 Dementia-Specific Auditory Deficits

Both LLMs were able to identify and describe the distinctive auditory deficits associated with the most known types of dementia:

For Alzheimer's Disease (AD):

- Auditory agnosia
- Impaired sound localization
- Reduced auditory memory
- Speech comprehension difficulties

For Lewy Body Dementia (LBD):

- Auditory hallucinations
- Impaired speech understanding
- Auditory distortion

For Frontotemporal Dementia (FTD):

- Auditory neglect
- Difficulty with voice recognition
- Impaired auditory attention

For Vascular Dementia (VD):

- Auditory processing deficits
- Reduced speech discrimination
- Slower auditory processing

3.3 Sound Segment Recommendations for Specific Scenarios

For **Scenario A** (FTD), both LLMs recommended similar sound segments with GPT-4o using a time-sequenced approach.

GPT-4o suggestion:

1. Soft Outdoor Ambience (7:00-7:15 am): birds chirping, distant wind through trees, soft morning rain
1. Subtle Household Sounds (7:15-7:30 am): muffled kitchen activity, footsteps, water running
2. Neutral, Natural Soundscapes (7:30-7:45 am): ocean waves, rustling grasses, distant farm animals
3. Morning Outdoor Ambience (7:45-8:00 am): urban morning sounds, faint church bells, light wind chimes

Claude 3.5 recommendation:

1. Gentle nature sounds: birds chirping, rain, rustling leaves
2. Household sounds: kitchen noises, clock ticking, footsteps
3. Animal sounds: purring cat, quiet dog barking, cow mooing
4. Weather sounds: light wind, distant thunder, waves
5. Human voices: soft speech, quiet laughter, humming
6. Ambient outdoor sounds: park sounds, street sounds, market sounds
7. Calming white noise: fan or air conditioning hum, soft static

For scenario B (comparing AD to FTD), both LLMs highlighted specific distinctions:

For AD:

- Familiar, memory-evoking sounds
- Simple and repetitive patterns
- Emotionally positive or natural sounds

For FTD, both emphasized on:

- Non-social, neutral sounds
- Simple, non-triggering sounds
- Avoiding complex social cues

3.4 3.4 Comprehensive Sound Segment Matching

When provided with detailed information about sound segments (including ID, labelling, semantic complexity, and affective information), both LLMs demonstrated matching capabilities with some similarities:

GPT-4o recommended:

- For AD: W0026 (rain falling), W0211 (birds chirping), W0088 (stream flowing), W0013 (music)
- For LBD: W0026, W0088, W0211, W0107 (crickets chirping)
- For FTD: W0088, W0016 (birds chirping), W0006 (frogs croaking), W0026
- For Posterior Cortical Atrophy: W0026, W0088, W0010 (ocean waves), W0211

Claude 3.5 recommended:

- For AD: W0016, W0026, W0088
- For VD: W0212, W0072, W0013
- For FTD: W0162, W0144, W0015
- For LBD: W0060, W0152, W0213

4. DISCUSSION

4.1 Comparative Analysis of LLM Performance

Both LLMs demonstrated some capabilities in understanding the complex relationship between dementia types, auditory deficits, and appropriate sound selection. However, notable differences emerged in their approaches:

GPT-4o tended to provide more structured, sequential recommendations with detailed explanations of why particular sounds would benefit specific dementia types. Its recommendations align with established therapeutic approaches, emphasizing familiarity for Alzheimer's and neutral, non-triggering sounds for frontotemporal dementia.

Claude 3.5 offered more diverse sound segment suggestions with greater attention to the affective dimensions and semantic complexity. It demonstrated some potential in distinguishing subtle differences between dementia types and providing tailored recommendations based on specific auditory deficits.

4.2 Semantic Complexity Considerations

The LLMs effectively utilized semantic complexity ratings in their recommendations, showing appropriate general selection patterns:

- Low complexity sounds (e.g., rain falling, stream flowing) were consistently recommended for Alzheimer's disease and other conditions with significant auditory processing deficits
- Moderate complexity sounds were selectively recommended for conditions where some auditory processing remained intact
- High-complexity sounds were generally avoided for most dementia types, with exceptions made for specific therapeutic purposes

4.3 Integration of Affective Information

Both LLMs demonstrated sophisticated use of affective information in their recommendations. They consistently preferred segments described as "pleasant," "calming," or "soothing" for conditions with anxiety features, while moderately stimulating sounds described as "vibrant" or "engaging" were recommended when appropriate for maintaining cognitive engagement.

4.4 Discrepancy between LLMs

Although both LLMs demonstrated the ability to select suitable segments based on specific dementias, their choices were inconsistent on specific segments.

4.5 Limitations and Ethical Considerations

Several limitations must be acknowledged:

1. Lack of direct audio processing: Current LLMs cannot directly analyze audio files, necessitating pre-labeled segments
2. Absence of personalization: Recommendations were based on dementia types rather than individual preferences and histories
3. Limited validation: The recommendations have not been extensively validated in clinical settings
4. Ethical considerations: The use of AI in dementia care raises important questions about agency, consent, and technological dependency

5. CONCLUSION

This study demonstrates the potential of LLMs to assist in selecting appropriate sound segments for soundscape augmentation in dementia care. By leveraging their ability to process complex information about dementia types, auditory deficits, semantic complexity, and affective dimensions, LLMs can provide nuanced recommendations that may enhance therapeutic interventions.

The findings suggest that LLMs could serve as valuable co-creators in designing personalized soundscapes, particularly in addressing the heterogeneity within dementia and tailoring interventions to specific auditory needs. However, LLMs should complement rather than replace human expertise at this time, with the final selection incorporating patient preferences, caregiver insights, and clinical judgment.

Future research should focus on:

1. Developing LLMs capable of directly processing audio files
2. Creating more personalized approaches that incorporate individual histories and preferences
3. Conducting clinical validation studies to assess the effectiveness of LLM-recommended sound segments
4. Establishing ethical frameworks for AI integration in dementia care
5. Exploring longitudinal applications to accommodate the progressive nature of dementia

This initial exploration suggests that integrating LLMs in soundscape design for dementia care represents a promising direction for enhancing the quality of life and reducing behavioural and psychological symptoms through personalized auditory environments.

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