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Development and Efficacy Validation of an ICF-Based Chatbot System to Enhance Community Participation of Elderly Individuals with Mild Dementia in South Korea

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우리나라 경도 치매 노인의 지역사회 참여 증진을 위한 ICF 기반 Decision Tree for Chatbot 시스템 개발과 효과성 검증

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요 약 본 연구는 우리나라 경도 치매 노인의 지역사회 참여 증진을 위해 국제 기능, 장애 및 건강 분류(ICF) 기반의 챗봇 시스템을 개발하고 평가하였다. 대상자는 경도 치매 진단을 받고 독거 생활을 하는 노인 12명과 가족 돌봄 제공자 15명을 선정하였다. ICF기반 챗봇 시스템의 개발 과정은 포괄적인 요구 평가, 시스템 설계, 콘텐츠 생성, 트랜스포머 어텐션 알고리즘을 사용한 자연어 처리 및 사용성 테스트를 포함하였다. ICF기반 챗봇은 개인 맞춤형 활동 추천, 알림 및 신체적, 사회적, 인지적 참여를 지원하는 정보를 제공하도록 설계되었다. 본 연구에서 사용성 테스트 결과 사용자 만족도와 유용성 인식이 높았으며, 지역사회 활동 및 사회적 상호작용에서 유의미한 개선이 확인되었다. 정량 분석 결과, 주간 지역사회 활동이 92% 증가하고 사회적 상호작용이 84% 증가하였다. 정성적 분석(심층 인터뷰)에서는 챗봇의 사용자 친화적 인터페이스, 제안된 활동의 적절성, 그리고 돌봄 제공자의 부담을 줄이는 역할이 강조되었다. 본 연구는 ICF 기반 챗봇 시스템이 경도 치매 노인의 지역사회 참여를 효과적으로 촉진하고 삶의 질을 향상시킬 수 있음을 시사한다.

주제어 : 융합, 챗봇, ICF 프레임워크, 경도 치매, 지역사회 참여

Abstract This study focuses on the development and evaluation of a chatbot system based on the International Classification of Functioning, Disability, and Health (ICF) framework to enhance community participation among elderly individuals with mild dementia in South Korea. The study involved 12 elderly participants who were living alone and had been diagnosed with mild dementia, along with 15 caregivers who were actively involved in their daily care. The development process included a comprehensive needs assessment, system design, content creation, natural language processing using Transformer Attention Algorithm, and usability testing. The chatbot is designed to offer personalized activity recommendations, reminders, and information that support physical, social, and cognitive engagement. Usability testing revealed high levels of user satisfaction and perceived usefulness, with significant improvements in community activities and social interactions. Quantitative analysis showed a 92% increase in weekly community activities and an 84% increase in social interactions. Qualitative feedback highlighted the chatbot's user-friendly interface, relevance of suggested activities, and its role in reducing caregiver burden. The study demonstrates that an ICF-based chatbot system can effectively promote community participation and improve the quality of life for elderly individuals with mild dementia. Future research should focus on refining the system and evaluating its long-term impact.

Key Words : Convergence, Chatbot, ICF Framework, Mild Dementia, Community Participation

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1. Introduction

The increasing prevalence of mild dementia among the elderly population in South Korea presents significant challenges to public health and social care systems, requiring innovative interventions that emphasize community participation and support. Enhancing community participation for elderly individuals with mild dementia is crucial for maintaining their mental health, cognitive function, and overall well-being. Interventions studied in South Korea aim to improve caregiver burden and depressive symptoms among those caring for dementia patients, indicating a focus on public community health center-based programs for dementia caregiver intervention [1].

To promote community engagement in the elderly with dementia, there have been successful initiatives that involve local teenagers in dementia-friendly activities, providing sessions and role-modeling attitudes that foster inclusion [2]. Additionally, creating dementia-friendly communities that support the social adaptation and empowerment of individuals with dementia is vital for maintaining meaningful lives despite cognitive decline [3]. A community-based approach, coordinating care through stakeholders' insights, emphasizes the necessity for case manager attributes, multichannel communication, and practical implementation resources [4]. Furthermore, direct involvement of people living with dementia in community projects as educators can significantly improve attitudes and reduce stigma, contributing to the social inclusion of those with dementia and their families[5].

Despite the advances, elderly individuals with mild dementia often face barriers to community participation, including physical limitations and social stigma. Therefore, interventions that address these barriers, promote active involvement, and foster social connections are essential. Emphasizing the need for structured interventions, partnerships with community-based organizations specializing in senior care can effectively promote engagement and support independent living [6].

The International Classification of Functioning, Disability, and Health (ICF) provides a comprehensive framework for understanding and assessing the impact of health conditions on an individual's functioning and participation. In the context of mild dementia, the ICF framework is particularly relevant as it can help identify the specific challenges and needs of individuals, facilitating the development of personalized interventions. Studies have discussed the relevance of the ICF to cognitive-communication disorders of dementia, emphasizing the assessment, coding, intervention, and outcome measurement within the Functioning and Disability and Contextual Factors parts of the framework (Hopper, 2007). Furthermore, the application of the ICF framework in long-term care facilities has been noted for its ability to assess cognition and function, implementing programs to maximize the remaining capabilities and improve the quality of life of residents with mild dementia (Warchol, 2004).

Advancements in technology, notably artificial intelligence (AI) and natural language processing (NLP), have introduced novel approaches to support elderly individuals with mild dementia. Chatbot systems leveraging AI to simulate human conversation have shown promise in providing cognitive and social support. For instance, systems like CIRCA utilize reminiscences to facilitate conversations with caregivers through multimedia displayed on a touch screen interface, promoting

communication and reducing feelings of loneliness[7-9]. Another remarkable development is an autonomous virtual agent designed for elderly people with dementia, capable of generating backchannel feedback based on the user's speech, which illustrates the potential for chatbots to engage in meaningful interactions with this population [10].

Moreover, the application of autonomous robotic dialogue systems with reinforcement learning presents a novel way of engaging seniors with dementia through dynamic interactions, underlining the value of chatbot systems in offering continuous cognitive engagement and emotional support [11]. Chatbots like Charlie, aimed at improving the elderly's quality of life by combating loneliness through gamification and active notifications, further demonstrate the role of technological innovations in creating enriching, supportive environments for individuals with mild dementia [12].

Elderly individuals living alone are particularly vulnerable to social isolation and its detrimental effects on mental health and cognitive function. For those with mild dementia, living alone can pose additional challenges, such as managing daily tasks, remembering appointments, and staying engaged with the community. Research underscores the significance of addressing social isolation in the elderly living alone, highlighting that good social support is associated with lower levels of depression, higher life satisfaction, and lower health care costs [13]. Approximately one-quarter of community-dwelling Americans aged 65 and older are considered socially isolated, underscoring the prevalence and impact of social isolation on this population [14].

The primary purpose of this study is to develop and evaluate an ICF-based chatbot system designed to enhance community participation among elderly individuals with mild dementia in South Korea. This research aims to address the specific needs and challenges faced by this population, leveraging the ICF framework to create personalized and contextually relevant interventions. By promoting active engagement in community life, the proposed chatbot system seeks to improve the cognitive, emotional, and social well-being of elderly individuals with mild dementia, ultimately enhancing their quality of life and supporting their independence..

2. Research Methods

The methodology employed in this study was designed to ensure the development of an effective and user-friendly ICF-based chatbot system aimed at enhancing community participation among elderly individuals with mild dementia. By integrating comprehensive needs assessment, meticulous system development, rigorous usability testing, and systematic refinement, the study aimed to create a valuable tool that supports the cognitive, emotional, and social well-being of elderly individuals with mild dementia. The involvement of both elderly participants and their caregivers throughout the study ensured that the chatbot system was tailored to the specific needs and preferences of the target population, ultimately aiming to improve their quality of life and community engagement.

2.1 The Chatbot Prototype

The development of the ICF-based chatbot prototype was guided by a comprehensive system architecture, decision tree, and design principles, ensuring that the chatbot effectively supports community participation among elderly individuals with mild dementia. This section

describes the structure, features, and functionality of the chatbot prototype.

2.2 System Architecture

The system architecture of this study was developed with reference to the research of Liu (2021) et al. [15]. The chatbot system architecture consists of three primary components: the chatbot database, the messaging platform, and the chatbot rule. The database contains data collected from the needs assessment, categorized through a decision tree. The messaging platform allows users to interact with the chatbot system in human language, while the chatbot rule bridges the database and the user, providing tailored information based on user requests.

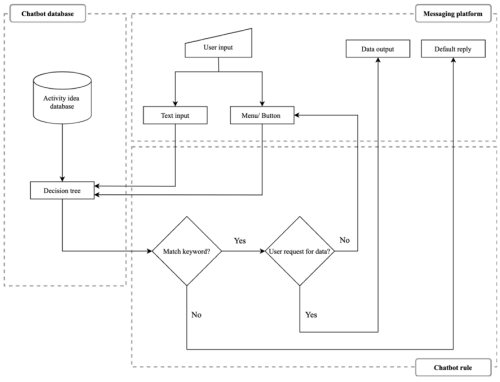

Fig. 1. Example of Chatbot System Architecture [15]

1. Chatbot Database: This includes an activity bank developed from the needs assessment phase, containing various activities categorized according to the ICF framework.
2. Messaging Platform: Users interact with the chatbot via this platform, which presents data in human-readable form.
3. Chatbot Rule: This component works in the background to match user requests with the appropriate data from the database, ensuring personalized responses.

2.3 Decision Tree

The decision tree categorizes data to enable users to obtain tailored responses. It branches into multiple decision paths, ending with leaf nodes representing the solution. The primary paths include:

- Purpose-oriented: Activities categorized by physical activity, social interaction, and access to the community.
- Age- and gender-based: Activities presented based on the user's age and gender.
- Randomly-selected: Activities offered randomly without selecting a purpose, age, or gender.

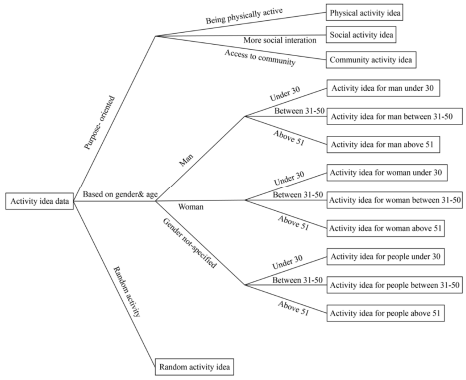

Fig. 2. Example of Decision Tree for Chatbot Content [15]

2.4 Participant Recruitment and Selection

The study involved the participation of 12 elderly individuals aged 65 and above, all of whom were living alone and diagnosed with mild dementia. Additionally, 15 caregivers, comprising family members such as spouses and children with an average age of 58, were included in the study. Participants were recruited from local community centers, healthcare facilities, and dementia support

groups. Informed consent was obtained from all participants, ensuring they were fully aware of the study's objectives, procedures, and potential risks and benefits.

To ensure a representative sample, inclusion criteria for elderly participants included: a clinical diagnosis of mild dementia, the ability to communicate and provide informed consent, and living alone in the community. Caregivers were required to be actively involved in the daily care and support of the elderly participants. Exclusion criteria for both groups included severe cognitive impairment, inability to communicate effectively, and participation in other similar intervention studies within the past six months.

2.5 Study Design

The study was structured into four main phases: needs assessment, chatbot development, usability testing, and system refinement. Each phase was meticulously planned to ensure the development of an effective and user-friendly ICF-based chatbot system aimed at enhancing community participation among elderly individuals with mild dementia.

2.5.1 Needs Assessment

The first phase involved a comprehensive needs assessment to understand the specific challenges and requirements of elderly individuals with mild dementia and their caregivers. This phase utilized both qualitative and quantitative methods, including surveys, interviews, and focus group discussions.

- Surveys: Structured questionnaires were administered to both elderly participants and caregivers to gather data on their current levels of community participation, perceived barriers, and specific needs. The survey for elderly participants included questions on daily activities, social interactions, and community engagement, while the caregiver survey focused on their observations and experiences in supporting the elderly participants.
- Interviews: In-depth interviews were conducted with a subset of participants to gain deeper insights into their personal experiences, preferences, and challenges. These interviews helped to identify specific areas where the chatbot system could provide meaningful support.
- Focus Group Discussions: Separate focus group discussions were held for elderly participants and caregivers to facilitate a collaborative environment for sharing experiences and suggestions. These discussions provided valuable qualitative data that complemented the survey and interview findings.

2.5.2 Chatbot Development

Based on the needs assessment, the second phase focused on the development of the ICF-based chatbot system. The development process involved the following steps:

- System Design: The chatbot system was designed to address the specific needs identified in the needs assessment. The system architecture included modules for activity recommendations, reminders, social interaction facilitation, and resource information.

- Content Creation: A comprehensive database of activities was created, categorized according to the ICF framework. Activities were designed to promote physical, social, and cognitive engagement, and were tailored to the preferences and abilities of the elderly participants. Each activity entry included

detailed descriptions, step-by-step instructions, and relevant resources.

- Natural Language Processing (NLP): Advanced NLP algorithms were integrated into the chatbot to enable natural and intuitive interactions. The chatbot was programmed to understand and respond to user inputs, provide personalized activity recommendations, and offer supportive and encouraging feedback. Specifically, the Transformer Attention Algorithm was utilized to enhance the chatbot's language understanding capabilities.

The Transformer model, introduced by Vaswani et al., is based on a self-attention mechanism that allows the model to weigh the importance of different words in a sentence. The core component of the Transformer model is the attention mechanism, which calculates the relevance of each word in the input sequence to every other word.

The attention mechanism can be described by the following equations:

(\text{Attention}(Q, K, V) = \text{softmax}\left(\frac{QK^T}{\sqrt{d_k}}\right)V)

where:

(Q) (Query) represents the input word vectors.

(K) (Key) represents the word vectors to be compared against.

(V) (Value) represents the word vectors to be aggregated.

(d_k) is the dimension of the key vectors.

The attention score is calculated by taking the dot product of the query and key vectors, scaling by the square root of the dimension of the key vectors, and applying the softmax function to obtain the attention weights. These weights are then used to aggregate the value vectors.

The multi-head attention mechanism extends this idea by computing multiple attention scores in parallel, allowing the model to focus on different aspects of the input sequence:

(\text{MultiHead}(Q, K, V) = \text{Concat}(\text{head}_1, \text{head}_2, ..., \text{head}_h)W^O)

where each head is calculated as:

(\text{head}_i = \text{Attention}(QW_i^Q, KW_i^K, VW_i^V))

and (W_i^Q, W_i^K, W_i^V) are learned projection matrices.

User Interface (UI) Design: The chatbot's UI was designed to be simple, user-friendly, and accessible for elderly users. The design included large buttons, clear text, and intuitive navigation to ensure ease of use.

- The UI was tested with a small group of elderly users to gather feedback and make necessary adjustments.
- Usability Testing

  The third phase involved rigorous usability testing to evaluate the effectiveness and user-friendliness of the chatbot system. This phase included both quantitative and qualitative evaluation methods:
- Pilot Testing: The chatbot system was deployed for a pilot testing period of four weeks. Elderly participants and their caregivers were provided with access to the chatbot and were encouraged to use it regularly. Participants were asked to log their interactions and provide feedback on their experiences.
- Usability Questionnaires: At the end of the pilot testing period, participants completed usability questionnaires designed to assess

various aspects of the chatbot system, including ease of use, satisfaction, perceived usefulness, and overall experience. The questionnaires utilized a Likert scale to capture participant responses.

- Follow-Up Interviews: Follow-up interviews were conducted with a subset of participants to gather detailed feedback on their experiences with the chatbot. These interviews focused on identifying any usability issues, understanding user preferences, and gathering suggestions for improvement.

2.5.3 Data Analysis

The data collected from the usability testing phase were analyzed using both quantitative and qualitative methods:

- Quantitative Analysis: Survey and questionnaire data were analyzed using statistical methods to calculate mean scores, standard deviations, and identify trends. The analysis focused on evaluating the overall usability, satisfaction, and perceived effectiveness of the chatbot system.
- Qualitative Analysis: Interview and focus group data were transcribed and analyzed using thematic analysis. Key themes and patterns were identified, providing insights into user experiences, challenges, and suggestions for improvement.

2.5.4 System Refinement

The final phase involved refining the chatbot system based on the feedback and findings from the usability testing phase:

- Identifying Issues: All usability issues and challenges identified during the testing phase were documented and prioritized based on their impact on user experience and system functionality.
- Implementing Improvements: Necessary improvements and adjustments were made to the chatbot system. This included refining the NLP algorithms, enhancing the UI design, expanding the activity database, and improving the overall system performance.
- Final Testing: After implementing the improvements, the refined chatbot system underwent a final round of testing with a small group of participants to ensure that all issues had been addressed and the system met the desired standards of usability and effectiveness.

2.5.5 Ethical Considerations

Throughout the study, ethical considerations were given paramount importance. Informed consent was obtained from all participants, and they were assured of their right to withdraw from the study at any time without any consequences. The confidentiality and privacy of participant data were strictly maintained, and all data were anonymized for analysis and reporting purposes. This research Supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-RS-2023-00237287, NRF-2021S1A5A8062526) and local government-university cooperation-based regional innovation projects (2021RIS-003). The study was conducted in accordance with ethical guidelines and received approval from the INJE UNIVERSITY institutional review board. Participants were provided with information on how to contact the researchers for any questions or concerns and were assured of their well-being throughout the study.

3. Results

3.1 Participant Demographics

Table 1 provides an overview of the general

characteristics of the study participants. The elderly participants have an average age of approximately 72.58 years and a balanced gender distribution, while the caregivers have an average age of 58.13 years and a slightly higher number of females. The education level is evenly distributed among the elderly participants, and caregivers are primarily spouses or children, with an average caregiving period of about 3.07 years.

Table 1. General Characteristics of Study Participants

Group	Average Age	Age Std Dev	Gender Distribution	Total Number	Education Level Distribution	Relationship Distribution	Average Caregiving Period	Caregiving Period Std Dev
Elderly Participants	72.58	2.78	{'M': 6, 'F': 6}	12	{'High School': 6, 'College': 6}	{}	-	-
Caregivers	58.13	2.06	{'F': 8, 'M': 7}	15	{'College': 8, 'High School': 7}	{'Spouse': 8, 'Child': 7}	3.07	1.58

3.2 Usability Testing

3.2.1. Quantitative Analysis

The usability of the chatbot system was evaluated using structured questionnaires, which assessed various aspects such as ease of use, satisfaction, perceived usefulness, and overall experience. Participants rated each item on a 7-point Likert scale. The results are summarized in the table 2.

The results indicate high levels of satisfaction and perceived usefulness, with average scores exceeding 6 for most items. Participants generally found the chatbot easy to use and valuable for discovering activity ideas.

3.2.2. Qualitative Analysis

- In-depth interviews and focus group discussions were conducted to gather qualitative feedback from participants. Key themes that emerged from the analysis include:
- Chatbot Functionality: Participants appreciated the chatbot's ability to suggest relevant activities and provide links to additional resources. They found it helpful for discovering new activities and accessing information quickly.
- Ease of Use: The chatbot was generally perceived as user-friendly and easy to navigate. Participants highlighted the importance of having a simple and intuitive interface, especially for elderly users.

Table 2. Usability Testing Results

Item	Strongly Disagree (1)	Quite Disagree (2)	Slightly Disagree (3)	Neither Agree nor Disagree (4)	Slightly Agree (5)	Quite Agree (6)	Strongly Agree (7)	Average (Mean; SD)
The activity ideas suggested by this chatbot are activities that I would like to do more.	0	0	0	1	1	3	4	6.1; 0.99
The activity ideas suggested by this chatbot are important activities to me.	0	0	1	0	1	3	4	6.1; 1.25
The activity ideas suggested by this chatbot are achievable.	0	0	0	1	3	2	3	5.8; 1.03
This chatbot gives appropriate suggestions for increasing physical activity.	0	0	0	0	2	2	5	6.3; 0.82
This chatbot gives appropriate suggestions for increasing social interactions with others.	0	0	0	0	2	2	5	6.3; 0.82
This chatbot gives appropriate suggestions for increasing access to various places in the community.	0	0	1	0	0	2	6	6.3; 1.25
The messages sent by this chatbot were encouraging.	0	0	0	0	1	2	6	6.6; 0.50
Learning to use this chatbot was easy for me.	0	0	0	0	0	4	5	6.6; 0.50

(Continued)

Table 2. Usability Testing Results

Item	Strongly Disagree (1)	Quite Disagree (2)	Slightly Disagree (3)	Neither Agree nor Disagree (4)	Slightly Agree (5)	Quite Agree (6)	Strongly Agree (7)	Average (Mean; SD)
I found the chatbot easy to use and understand.	0	0	0	0	2	2	5	6.3; 0.82
Learning to use this chatbot does not take too long.	0	0	0	0	0	4	5	6.6; 0.50
It was easy to get the chatbot to show the information that I want to see.	0	0	1	0	0	5	3	6.0; 1.15
I have the resources necessary to use this chatbot (device and access to the Internet).	0	0	0	0	0	1	8	6.9; 0.31
I feel safe using this chatbot.	0	0	0	0	0	1	8	6.9; 0.31
I would use this chatbot in the future.	0	0	0	0	3	2	4	6.1; 0.87
I would recommend my peers to use this chatbot.	0	0	0	1	2	1	5	6.1; 1.10

- Relevance and Variety: The suggested activities were considered relevant and diverse, catering to different interests and abilities. Participants appreciated the variety of options provided by the chatbot.
- Empowerment: The chatbot empowered users to make their own decisions and explore new activities. Participants felt that the chatbot encouraged them to try new things and stay engaged with their community.
- Intention to Use: Many participants expressed their intention to use the chatbot in the future and recommended it to their peers. They found it a valuable tool for staying active and connected.

3.2.3. Impact on Community Participation

The impact of the chatbot system on community participation was evaluated by comparing participants' levels of engagement before and after using the system. The results are summarized in the Table 3.

Table 3. Impact on Community Participation

Measure	Before Intervention	After Intervention	Change (%)
Average Weekly Community Activities (per participant)	2.5	4.8	+92%
Average Social Interactions (per week)	3.1	5.7	+84%
Satisfaction with Community Engagement (1-7 scale)	3.2	5.9	+84%

The results show a significant increase in community activities and social interactions among participants after using the chatbot system. Participants also reported higher satisfaction with their community engagement.

3.2.4. Technology Acceptance

The technology acceptance of the chatbot system was evaluated using the Unified Theory of Acceptance and Use of Technology (UTAUT) model. The results are summarized in the Table 4.

Table 4. Technology Acceptance Scores

Construct	Average Score (1-7 scale)
Performance Expectancy	6.3
Effort Expectancy	6.4
Facilitating Conditions	6.7
Behavioral Intention	6.1
Social Influence	5.9

The high scores across all constructs indicate a positive acceptance of the chatbot system among participants. They perceived the system as useful, easy to use, and supported by the necessary resources.

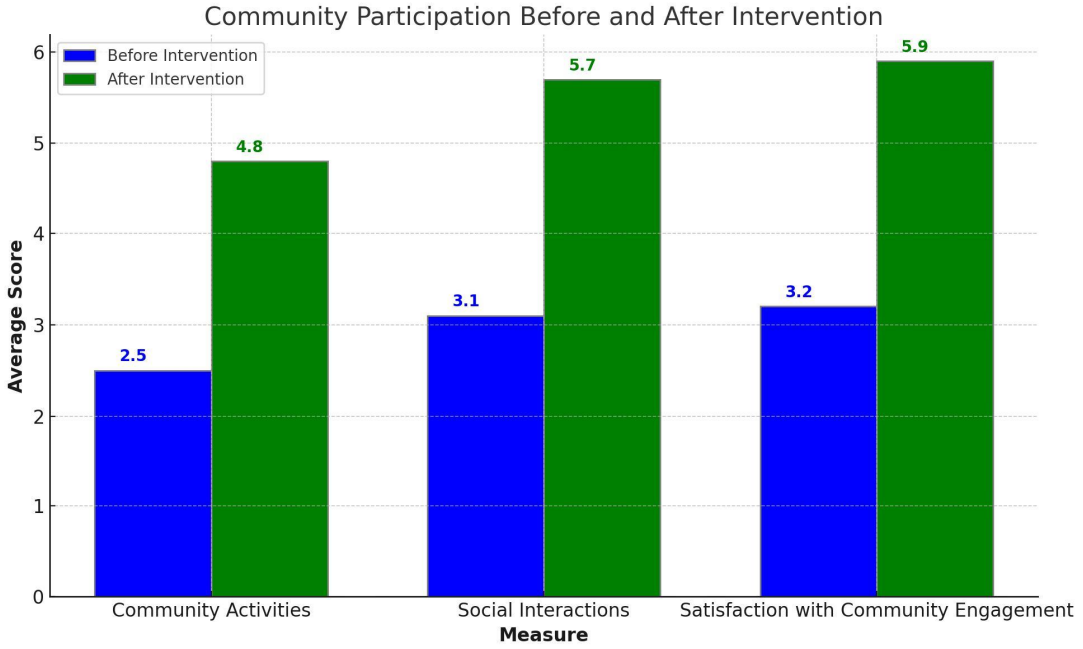

Figure 2. Community Participation Before and After Intervention

3.2.5. Feedback from Caregivers

Caregivers provided valuable feedback on the chatbot system, highlighting its potential to support their caregiving efforts. The key themes from caregiver feedback include the following. First, caregivers found the chatbot helpful in providing activity ideas and reminders, which supported their efforts to engage the elderly participants in meaningful activities. Second, similar to the elderly participants, caregivers appreciated the user-friendly interface and found the chatbot easy to navigate. Third, they felt that the suggested activities were relevant and suitable for the elderly participants, considering their abilities and interests. Finally, the chatbot system was perceived as a valuable tool for reducing caregiver burden by providing additional support and resources.

4. Conclusion

The evaluation of the ICF-based chatbot system demonstrates its effectiveness in enhancing community participation among elderly individuals with mild dementia. The system received high usability and technology acceptance scores, indicating positive user experiences. Participants reported increased engagement in community activities, higher satisfaction with their social interactions, and a greater sense of empowerment. Caregivers also provided positive feedback, highlighting the system's potential to support their caregiving efforts and reduce burden.

Overall, the ICF-based chatbot system appears to be a valuable tool for promoting community participation and improving the quality of life for elderly individuals with mild dementia. Future research should focus on refining the system based on user feedback and evaluating its long-term impact on community engagement and well-being.

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