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Prediction of BPSD Onset Using Multimodal Sensors: A Study on Dementia Patients in Long-Term Care

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Abstract. This study aims to predict the onset of Behavioral and Psychological Symptoms of Dementia (BPSD) using multimodal sensors, thereby improving dementia care. By analyzing behavior, sleep, and environmental data, we developed a predictive model to notify caregivers about the potential onset of BPSD, enabling timely intervention and reducing caregiver burden.

Keywords. BPSD, IoT, Machine Learning, Dementia Patient, Predictive Model

1. Introduction

The growing number of dementia patients poses significant challenges to caregiving. BPSD increases caregiver stress and impacts patient well-being in long-term care. Our research integrates behavior sensor data and environmental sensor data to predict the early onset of BPSD and provide actionable insights to caregivers.

2. Prediction Approach and Results

We utilized multimodal sensors, including ceiling-mounted behavior sensors and wall-mounted environmental sensors. Behavior sensors (HitomeQ [2]) comprise a near-infrared camera and a Doppler sensor. The camera captures human movement (moving time, moving distance, abnormal activities such as absentmindedly standing, wobble walking, etc.), while the Doppler sensor monitors sleep patterns (sleep time, awakening time, sleep rhythm, etc.). Environmental sensors (Omron 2JCIE-BU [3]) record data on temperature, humidity, light, and noise levels.

60 patients participated as subjects after providing signed informed consent. They resided in three different nursing facilities and ranged in age from 75 to 100. The sensors were installed in their private bedrooms, and round-the-clock sensor data was collected for each participant between January 2022 and June 2023. A total of 2,071 instances of BPSD onset were recorded by caregivers and used as the objective variable. The data were analyzed using machine learning (LGBM classification) to develop

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[2]https://www.konicaminolta.com/about/csr/social-innovation/case/care-support.html
[3]https://components.omron.com/us-en/products/sensors/2JCIE-BU

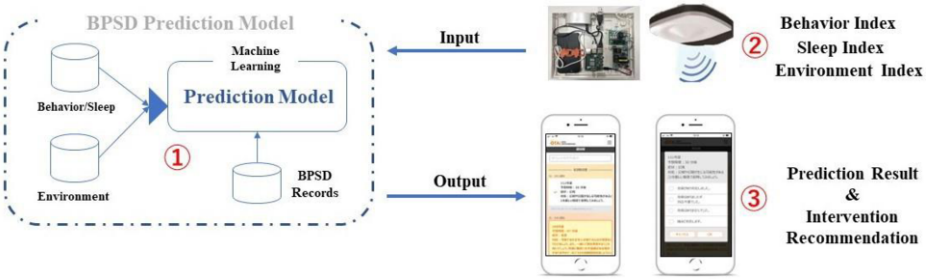

Figure 1. ① BPSD prediction model construction, ② sensors, ③ notification & recommendation application

Prediction Object	Precision	Recall	F1
(any) BPSD onset (without specifying individual symptoms)	**87.8%**	**63.7%**	**73.8%**
hyperactive symptoms (delusion, irritability, etc.)	71.8%	51.5%	60.0%
hypoactive symptoms (apathy, depression, etc.)	55.8%	23.1%	32.5%
daily living-related symptoms (day-night reversal, uncleanliness, etc.)	31.0%	12.8%	17.4%

Table 1. Evaluation of 5-fold cross validation $Precision = \frac{TP}{TP+FP}$ $Recall = \frac{TP}{TP+FN}$ $F1 = \frac{2 \times Precision \times Recall}{Precision + Recall}$

a predictive model as shown in Figure 1. The predictive model demonstrates high accuracy in forecasting daily BPSD onset (without specifying individual symptoms) and hyperactive symptoms, as shown in Table 1. Key explanatory variables include variations of temperature, humidity, and sleep rhythm. The system alerts caregivers to high-risk periods by a smartphone application, allowing proactive interventions.

3. Discussion

The integration of multimodal sensors and machine learning offers a robust solution for predicting BPSD. Our study highlights the importance of a comprehensive data-driven approach in dementia care. However, the prediction performance for hypoactive symptoms and daily living-related symptoms remains low, primarily due to insufficient instances and limited learning opportunities in the dataset. Besides, attempts to improve performance using techniques such as random over-sampling, under-sampling, and SMOTE were unsuccessful. To overcome these challenges, further validation with larger and more diverse datasets is essential to enhance the model's accuracy and reliability.

Additionally, we observed a peak in BPSD occurrences during August and September, which may be linked to weather instability, including summer storms in Japan. These conditions can cause significant atmospheric pressure changes, potentially triggering low-pressure disorders. Such disorders may disrupt sleep patterns and lead to abnormal behaviors, such as repetitive actions, which could exacerbate BPSD symptoms.

4. Conclusions

We proposed a novel method for predicting the onset of BPSD using multimodal sensor data, aiming to reduce caregiver stress and improve patient outcomes in long-term care. Future work will focus on refining the model and incorporating additional data sources to further enhance its predictive capabilities.