



**Case Report**

# Effects of Teleoperated Humanoid Robot Application in Older Adults with Neurocognitive Disorders in Taiwan: A Report of Three Cases

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**ABSTRACT**

Rising prevalence of major neurocognitive disorders (NCDs) is associated with a great variety of care needs and care stress for caregivers and families. A holistic care pathway to empower person-centered care is recommended, and non-pharmacological strategies are prioritized to manage neuropsychiatric symptoms (NPS) of people with NCDs. However, limited formal services, shortage of manpower, and unpleasant experiences related to NPS of these patients often discourage caregivers and cause the care stress and psychological burnout. Telenoid, a teleoperated humanoid robot, is a new technology that aims to improve the quality of life and to reduce the severity of NPS for persons with major NCDs by facilitating meaningful connection and social engagement. Herein, we presented 3 cases with major NCDs in a day care center in Taiwan who experienced interaction with the Telenoid. Overall, no fear neither distressed emotional response was observed during their conversation, neither worsening of delusion or hallucination after interaction with Telenoid. The severity of NCDs seemed to affect the verbal communication and the attention during conversation with Telenoid. Other factors, such as hearing impairment, insomnia, and environmental stimuli, may also hinder the efficacy of Telenoid in long-term care settings. Further studies with proper study design are needed to evaluate the effects of Telenoid application on older adults with major NCDs.

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**1. INTRODUCTION**

Rising prevalence of major neurocognitive disorders (NCDs) poses a great impact on physical, psychological, social, and economic dimensions on persons with diseases, caregivers, families, and whole society.<sup>1</sup> Globally, it is estimated that 50 million people were affected by major NCDs in 2015, which may become

82 million in 2030, and 152 million by 2050.<sup>2</sup> In Taiwan, the prevalence of major NCDs was 8.04%, and 18.76% for minor NCDs among the community-dwelling older adults, and the prevalence may be higher among those with frailty and multimorbidities.<sup>3</sup> In the average of 8-10 years of life expectancy after diagnosis, persons with major NCDs have more care needs related to their cognitive impairment, and frequent transition of

care needs due to neuropsychiatric symptoms as well as disability. A holistic, person-centered care pathway to empower patients is always recommended to improve those negative aspects related to NCDs, such as insecurity, low dignity, depression, and few social engagements.<sup>1,4</sup>

Neuropsychiatric symptoms (NPS), which over 90% of patients with major NCDs may develop at any stage over the disease course, substantially increased the risks of premature institutionalization, functional disability, cognitive decline, and even mortality for persons with major NCDs.<sup>5</sup> Aggression, delusion, and hallucination of agitated/psychotic clusters often lead to mistreatment and inappropriate care managements by physical or chemical restrains. Anxiety, nihilistic ideation, lack of initiatives, and psychomotor slowing of depressive/apathic clusters may worsen the conditions of social isolation and even mistreatment or neglect.<sup>5</sup> Among family caregivers and staff of long-term care facilities, NPS are highly associated with physical care stress and psychological burnout due to the inability to cope with those problems.<sup>6</sup> In addition to physical injuries coming from violent behaviors related to NPS, caregivers also found having higher risk of cardiovascular diseases, probably due to chronic inflammation and sympathetic overactivation. Moreover, over a third of caregivers reported depressive symptoms and about a half of care-givers reported anxiety due to emotional stress and psychological frustration.<sup>6</sup> Despite that non-pharmacological approaches are prioritized in the management of NPS, caregivers are often discouraged due to enormous care stress and psychological burnout, especially when the formal services and manpower are limited.

Teleoperated humanoid robot is a new technology that improves the quality of life and relieve the severity of NPS of patients with major NCDs by facilitating meaningful connection and social engagement.<sup>7</sup> This teleoperated design allows the caregivers keeping conversation as usual at a more relaxing atmosphere without worrying NPS and violence, and the human-like appearance of teleoperated humanoid robot promotes the initiation of communication with persons with major NCDs.<sup>8</sup> Animal-like robots provide companionship as pet to comfort the NPS of older adults with major NCDs. However, the teleoperated humanoid robot reduces users' potential emotional stress, and facilitates mutual interaction from family members through wireless connection system at homes, offices, or even when they are on vacations. Nevertheless, the "uncanny valley hypothesis" argues that the human-like appearance might provoke the feeling of dislike and the risk for delirium, delusion, and even worsened NPS, especially among older persons with cognitive impairment.<sup>9</sup>

The purpose of this study was to explore the

experiences on applying teleoperated humanoid robots among older participants with major NCD, to evaluate the subsequent influences on their NPS, to elucidate if any negative response related to uncanny valley hypothesis, and to explore the possibly affecting factors on successful application of robot technology in daily practices.

## 2. CASE PRESENTATION

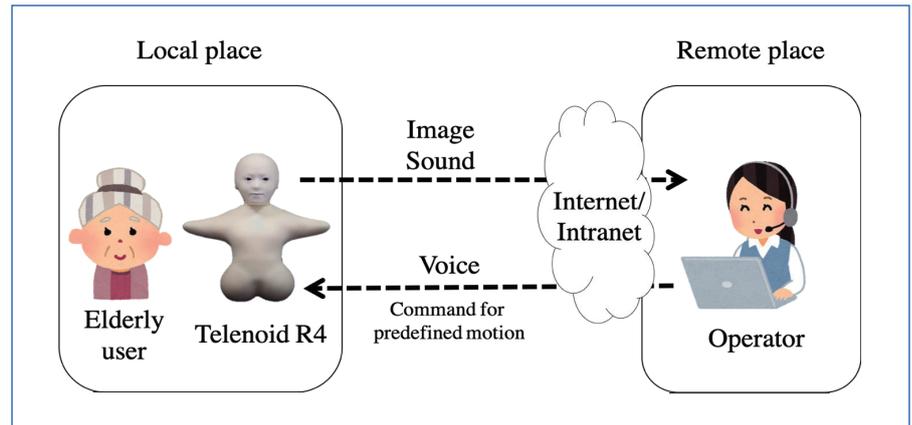
Three service recipients who received day care services at the uAge Day Care Center, Taipei Veterans Hospital, were invited for participation during July 15, 2018 and July 15, 2019. All participants received day care services with confirmed diagnosis for major NCDs, including Parkinson's disease dementia, Alzheimer's disease, and vascular dementia. Written informed consent were obtained after fully explanation to all participants and their families. Demographic characteristics, subtypes of major NCDs, chronic conditions, and regular medications were collected for all participants. Each participant would have mutual interaction with a staff of day care center in session 1, with their family in session 2, with humanoid robot operated by that staff in session 3, and finally the robot operated by their family in session 4. Each session allowed a free conversation during ordinary social interaction with the maximum of 20 minutes. On the final day, additional group session was arranged for all participants and Telenoid operated by staff to evaluate the interaction pattern and possible learning effect during ordinary conversation. The time distribution of participants' and partners' talking were recorded individually to calculate a time ratio of participant/partner. The attention paid on the partner with eye-to-eye contact was also estimated during each session. Neuropsychiatric symptom assessment by 12-items Neuropsychiatric Inventory (NPI) in Chinese version was performed on each individual before and 48 hours after mutual interaction.<sup>10</sup> This study was approved by the institutional review board of the Taipei Veterans General Hospital (IRB-VGHTPE No. 2018-07-020B).

Telenoid R4, a teleoperated, humanoid robot that developed by Osaka University and the Advanced Telecommunications Research Institute International, was employed for mutual interaction (Figure 1). It was covered by pleasant soft vinyl skin, sized approximately 50 cm in length, weighted 3.5 kgs, and could transmit a remote operator's voice based on an intact Wifi environment. Its physical movements were generated based on voice of the operator, using an online speech-driven head motion system.<sup>11</sup> Equipped with six independent actuators of eyeballs, mouth, neck, and both arms, Telenoid could also perform predefined behaviors, such as greeting or hugs using Graphical User Interface (GUI) buttons on the laptop screen (Figure 2). The application experiences among the elderly living in senior homes in Denmark and

**Figure 1.** Telenoid R4.



**Figure 2.** Illustration of teleoperating system.



Japan reported positive response through mutual interaction via Telenoid both for the elderly and the families.<sup>8,12</sup>

**Participant 1** is a 78-year-old lady diagnosed Parkinson’s disease dementia with Clinical Dementia Rating (CDR) of 1, i.e. mild severity. Neuropsychiatric symptoms observed in the day care center, including delusion, hallucination, dysphoria, anxiety, aberrant behaviors, and sleep disorders with the total NPI score 32 and regular use of quetiapine 25 mg every night. She always kept smiling with good eye contact over 95% of time during interaction with her partner of each session. High initiative was observed during conversation, but lower time ratio of participant/partner was found when the Telenoid was operated by staff rather than by family (Table 1). The participant was also very interested on Telenoid with hugging, touching, dressing and kissing during interaction. She presented more euphoric and more talkative after those sessions, but no worsening of NPS neither increased care stress on family after 48 hours.

**Participant 2** is an 85-year-old lady diagnosed with Alzheimer’s disease with her CDR of 2 (moderate severity). There were neuropsychiatric symptoms of apathy and fair intake at usual with total NPI score 11 and regular consumption of donepezil 10 mg every day. The participant would keep eye contact for over 80% of time with staff in session 1, but tended to respond by gestures and non-verbal language more than spoken sentences. Her attention was easily distracted by external stimuli during each session, and became tired soon due to insomnia at previous night. She looked confused, impatient, and unfamiliar with Telenoid in session 3 & 4 and did not have any verbal response to it. Even the partner spent about 5 minutes in each session, the conversation time of participant was less than 2 minutes in session 1 & 2, and

was 0 in session 3 & 4. No changes in NPI score was disclose at 48 hours after interaction.

Interestingly, after a good sleep prior to the group session, she became more curious about participant 1’s interaction with Telenoid, and paid more attention with a smile, and learned how to interact with Telenoid in group conversation. The performance was much better than that at individual’s session, and it was supposed group session would do help through connecting with their previous life experience or learning pattern of mutual interaction.

**Participant 3** is an 86-year-old gentleman with vascular dementia and his CDR was 2 (moderate severity). There were neuropsychiatric symptoms of hallucination, agitation, dysphoria, disinhibition, irritability, aberrant behaviors, and sleep disorders

**Table 1.** Distribution of conversation time and attention of participants.

	Conversation Time of Participant (Seconds)	Conversation Ratio (Participant/Partner)	Attention on Partner (%)
<b>Participant 1, female, 78 years old, with Parkinson’s disease dementia, CDR=1, NPI=32</b>			
*Session 1	588	1.87	> 95
Session 2	484	1.71	> 95
Session 3	357	1.28	> 95
Session 4	475	1.93	> 95
<b>Participant 2, female, 85 years old, with Alzheimer’s disease, CDR=2, NPI=11</b>			
Session 1	117	0.29	90
Session 2	78	0.20	50
Session 3	0	0	0
Session 4	0	0	0
<b>Participant 3, male, 86 years old, with vascular dementia, CDR=2, NPI=64</b>			
Session 1	481	6.33	90
Session 2	328	1.91	90
Session 3 <sup>##</sup>	27	0.10	20
Session 4 <sup>###</sup>	334	2.39	30

CDR: clinical dementia rating; NPI: neuropsychiatric inventory.  
 \*Partner of each session: 1: staff; 2: family; 3: Telenoid by staff; 4: Telenoid by family.  
<sup>##</sup>Partner: group session with family assistant and Telenoid by staff.  
<sup>###</sup>Partner: group session with staff assistant and Telenoid by family.

with total NPI score 64 but not in use of any antipsychotic agent. The participant would keep eye contact for over 80% of time with staff and family during conversation with high initiative, but the interaction was partially interfered by his hearing impairment that the staff and family needed talking in a shorter distance with louder voice for better understanding. The voice from Telenoid was not well heard by the participant, he paid less attention on Telenoid and turned to the staff for further talking in session 3 & 4. No influence was found on NPI scores before and 48 hours after interaction.

### 3. DISCUSSION

To the best of our knowledge, this is the first study to evaluate the hypothesis of uncanny valley by NPI scores before and 48 hours after Telenoid interaction among participants with major NCDs. Mutual interaction with human-like robot did not evoke a response of fear or dislike during the process, and no NPS worsening was noted after the trial. One participant was found more talkative and euphoric with minimal disturbance of sleep, but those NPS did not worsen nor increase the care burden on family. Although NPI had been evaluated in the previous study on Telenoid application in Japan, the NPI scores were tested in 6 months interval as routine evaluation and not actually represented the influence of uncanny valley.<sup>8</sup> Experiences from the three participants partially confirmed the feasibility of Telenoid application on older people with major NCDs.

As presented in this study, participants 1 & 3 with agitated/psychotic NPS had better mutual interaction with Telenoid than participant 2 with depressive/apathic NPS. Although agitated/psychotic NPS have been reported as the most difficult symptoms for caregivers and may lead to premature institutionalization,<sup>13</sup> observation from this study implied the potential of retain their autonomy and a possibility for active social connection. However, very limited data were available to evaluate the relationship between social interaction, clinical outcome, and different subtypes of NPS at present.

Although NPS was not worsened after Telenoid interaction, the severity of major NCDs hindered the fluency of mutual communication. According to previous studies, the application of telepresence robot helped to improve social connection and to stabilize the mood among persons with major NCDs.<sup>7</sup> However, participants with more advanced severity of NCDs were found progressively losing their ability on verbal communication, mostly responding conversations by gestures or nonverbal language, and having difficulty when paying attention on specific topics for a longer duration.<sup>14</sup> Therefore, the principles for choosing potential candidates, the strategies as individual or group interaction, and the possible

demonstration of nonverbal language by robot need more sophisticated design. As evidence reported in current studies, the application of Telenoid might be more effective among older adults with retained ability for verbal communication. Meanwhile, it was also important to minimize all possible interfering factors on physical, psychological, and environmental aspects before mutual interactions, such as insomnia, hearing impairment, and lack of gesture response that presented among the participants. Gender difference might also affect the response of Telenoid application. The male participant showed less interested in Telenoid talking and dressing due to lacking such experience of playing doll in childhood, therefore a linkage with life experience should be considered on robot-care application in the future.

### 4. CONCLUSION

Teleoperated humanoid robot provides a feasible strategy to establish mutual interaction between older adults with major NCDs and caregivers at elsewhere. No fear or dislike response to its human-like appearance was observed during their interaction. Improvement in social connection and stabilization in mood status were noted, but the ability of communication may confound the interaction. Further study with larger scale is needed to evaluate the efficacy of Telenoid applications.

### CONFLICTS OF INTEREST STATEMENT

The authors declare that they have no competing interest.

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