Can Software Robot Enhance Cognitive Capacity of Senior People?: a Longitudinal Exploratory Field Study with Korean Elderlies

(Extended Abstract)

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Background: A substantial increase in the global population suffering from dementia constitutes a high demand on tools for adequate treatment(Won, 2019). Non-pharmacological treatments such as digital therapeutics have been favored due to its easy accessibility and ubiquity in the use of the cognitive intervention especially after COVID 19 pandemic(Quail, 2021). Within this context, we propose a *Care-and-Cure ~~service~~*, a mobile-based online conversational agent facilitating cognitive capacity of older adults at risk of cognitive impairment. We found that *Care-and-Cure ~~service~~* distinctly improved the cognitive/emotional function of older adults, which was positively associated with the amount of use.

Objective: *Care-and-Cure* consists of two components. Sammy is a chatbot also known as a conversational agent. Our chatbot *Sammy* proactively provides cognitive games designed to improve individuals' cognitive functions (e.g., calculation, language, concentration, executive function, memory, space-time). *Sammy* provides 15 games to improve 6 cognitive domains. The game consists of five difficulty levels, and the level increases based on the user's correct answer rate. *Smart Our Community* is a group chat environment, which constitutes a virtual space for social interaction between participants. *Smart Our Community* is a supportive service that aims to increase users' willingness for Sammy. The purposes of this study were to examine the effects of the *Care-and-Cure service* on cognitive function and to investigate whether the group chat helped participants to motivate the willingness to use the *Care-and-Cure service*.

Methods: For this study, we have recruited a total of 133 participants (age mean = 64.75, range from 50 to 80 years old) who are not demented. All participants were provided the Care-and Cure service for 12 weeks. The primary outcomes were changes in K-MMSE scores between the baseline and after 12 weeks of use. The secondary outcomes were the willingness to use the service assessed by TWEETS scores and participants' log data, degree of social support (measured by MOS-SSS) and depression scores (measured by geriatric depression scale). We also investigated if the amount of use of *Care-and-Cure* service was associated with the improvement in cognitive function. In order to find out the mediating effect between '*Smart Our Community*' participation and cognitive reinforcement game participation, the mediating effect was verified through hierarchical regression analysis by Baron and Kenny. A paired sample *t*-test was used to detect significant differences before and after intervention in the Care and Cure program. An independent sample *t*-test was conducted for comparison between groups. In addition, a multiple linear regression analysis was conducted to verify the relative influence of '*Smart Our Community*' use and cognitive reinforcement game use on subjects' social support and willingness to participate.

Results: *Care-and-Cure* distinctly improved the cognitive function of the participants. For all participants, the K-MMSE score significantly increased ($p < 0.0001$) with a moderate effect size (0.35; Hedge's g). The following post-hoc analyses revealed that a lower K-MMSE group of participants showed a significant increase in cognitive capacity with a very large effect ($p < 0.001$; effect size = 1.17, Hedge's g) while a higher K-MMSE group showed no significant effect at all. When we further investigated the impact of the amount of time to use *Care-and-Cure,* we found that the more frequent use of *Care-and-Cure* ensured a significantly higher improvement in cognitive function with a large effect ($p < 0.001$; effect size = 0.48, Hedge's g). In detail, both *Sammy* and *Smart Our Community* led significant improvement with a large effect size of 0.48 (Hedge's g; $p < 0.001$) and 0.49 (Hedge's g; $p < 0.05$), respectively, in a group with more frequent use. With regards to non-cognitive capacity, *Care-and-Cure* also enabled the statistically significant enhancement in a degree of social support ($p < 0.001$) and a degree of willingness to participate ($p < 0.05$). We also found that the scores of Geriatric depression scales significantly decreased after 12 week use of *Care-and-Cure* service($p < 0.01$).

Conclusions: We found that *Care-and-Cure successfully* improved not only cognitive function but also depressive mood, which was associated with the amount of use of the service. In addition, we also found that *Smart Our Community*, a virtual space for social interaction, helped participants be motivated to use/ boost the will to use Sammy, which affects the usage time of the *Care-and-Cure* services. Our study may suggest that improving social interaction among the participants could be the key strategy to improve the engagement of digital therapeutics use..

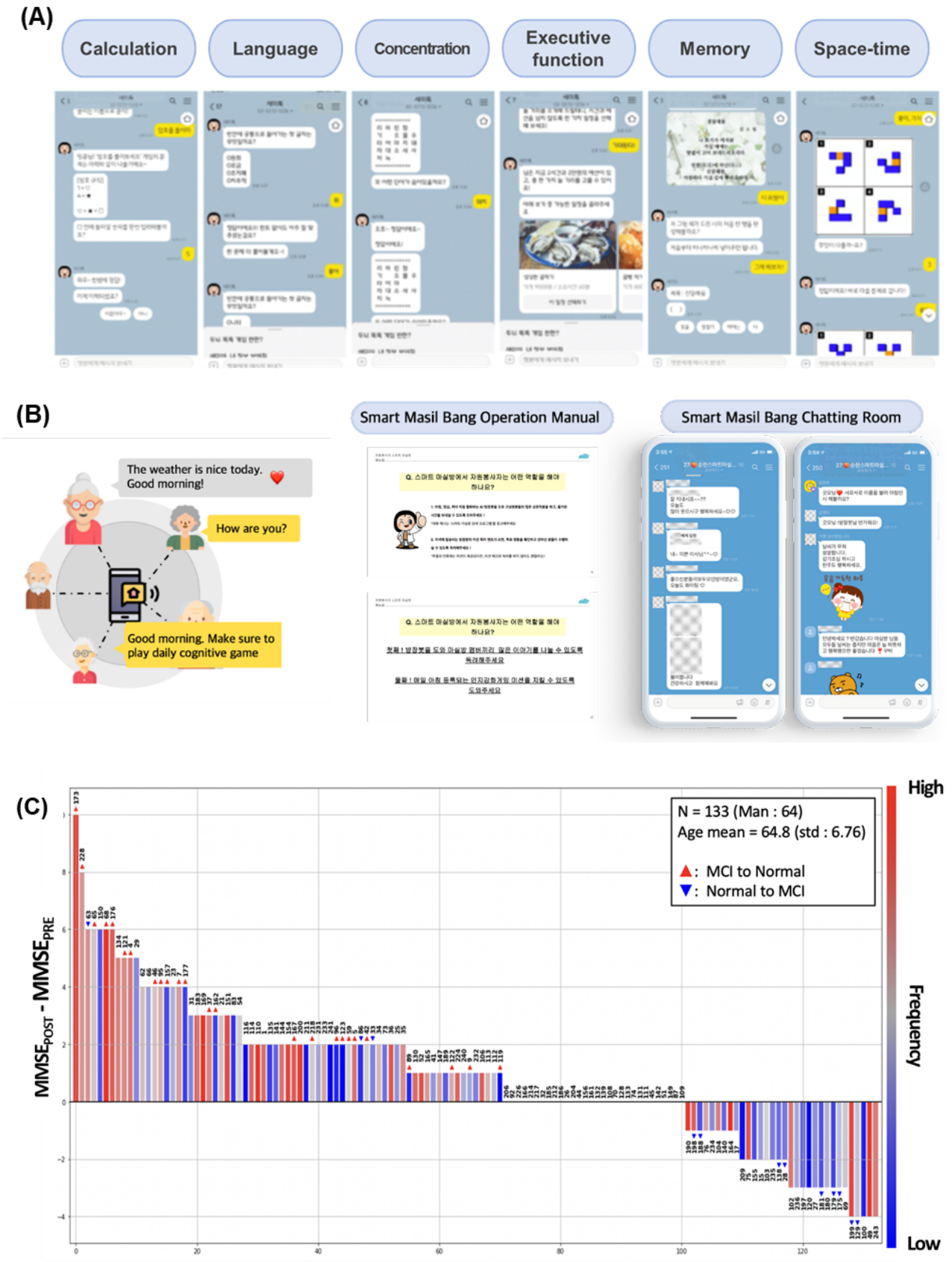

Figure 1. *Care-and-cure* overview. **(A)** It is *Sammy* subserving chatbot-based games for improving six categories of high-level cognitive functions. Users are required to carry out four sets of games per day to achieve a daily mission given by *Sammy*. **(B)** *Smart masil bang* is a group chat for five or more people gather in messenger room and take care of each other's safety. In the messenger

room, people encourage each other to play brain training games, or greet and talk freely with others every day. *Smart masil bang* is operated according to the operational manual. **(C)** Summary on changes in MMSE score, before and after the treatment, per each subject. The x-axis is a subject id, and the y-axis is the delta (= $MMSE_{post}$ - $MMSE_{pre}$) of each subject. The bar colour stands for the amount of time (i.e., frequency) the subject used *Care-and-cure* for the whole period of the experiment. The red triangle means that the subject's status of cognitive deficits is improved (from under the risk of MCI to normal. We called it MCI later), and the blue triangle is the opposite - a decline (from normal to under the risk of MCI).

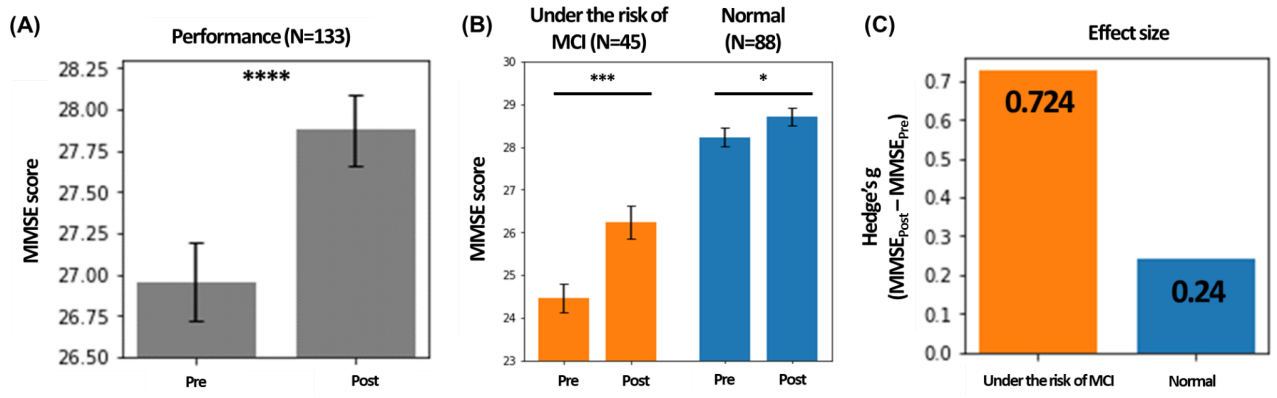

Figure 2. Overall result. **(A)** Changes in MMSE score before and after the treatment on average. The MMSE score measured after the whole experiment for 12 weeks is significantly higher than that before the experiment (paired *t*-test; $p < 0.0001$). **(B)** The result of changes in MMSE score between an MCI and a normal group. A subject whose MMSE score is under one standard deviation is categorised as an MCI group, and normal otherwise. Both the MCI and the normal group showed a significant increase in the MMSE score after the treatment (paired *t*-test; $p < 0.0001$ for the MCI; $p < 0.05$ for the normal). **(C)** The effect size. The MCI group exhibited a large effect size while the normal group showed a weak effect size.

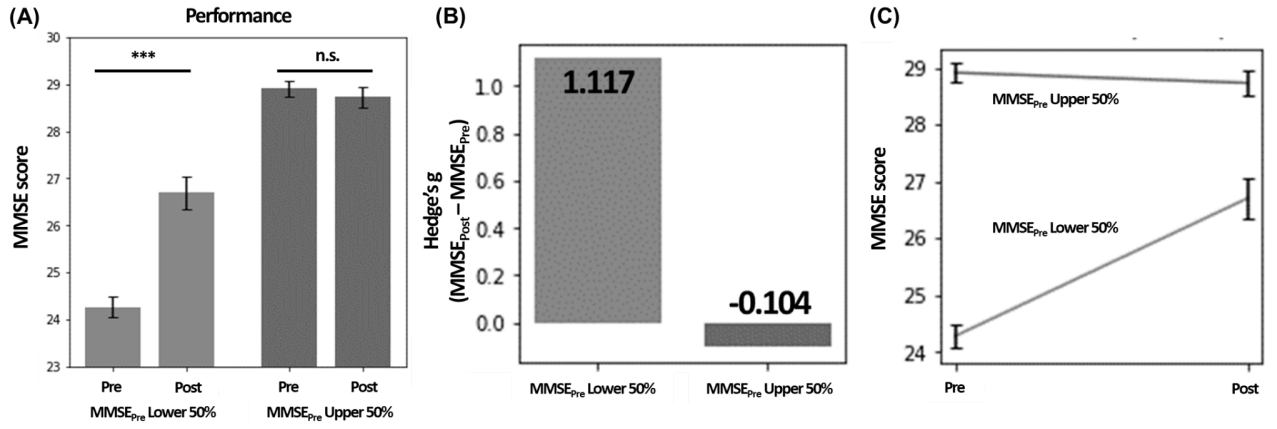

Figure 3. Performance depending upon the MMSE score before the treatment. We divided the subjects into two groups based upon the MMSE score before the treatment: we categorised

subjects in the lower 50 percentile of the MMSE score into a lower 50% group, and an upper 50% otherwise. **(A)** Changes in MMSE score of the two groups before and after the treatment on average. The lower the performance is, the higher effect on the improvement exhibited. The lower group showed a significant increase in MMSE score after the treatment (paired *t*-test; $p < 0.001$) while the upper group showed no significance at all. **(B)** The Effect size. A very large effect size was observed in the lower group. **(C)** Interaction effect.

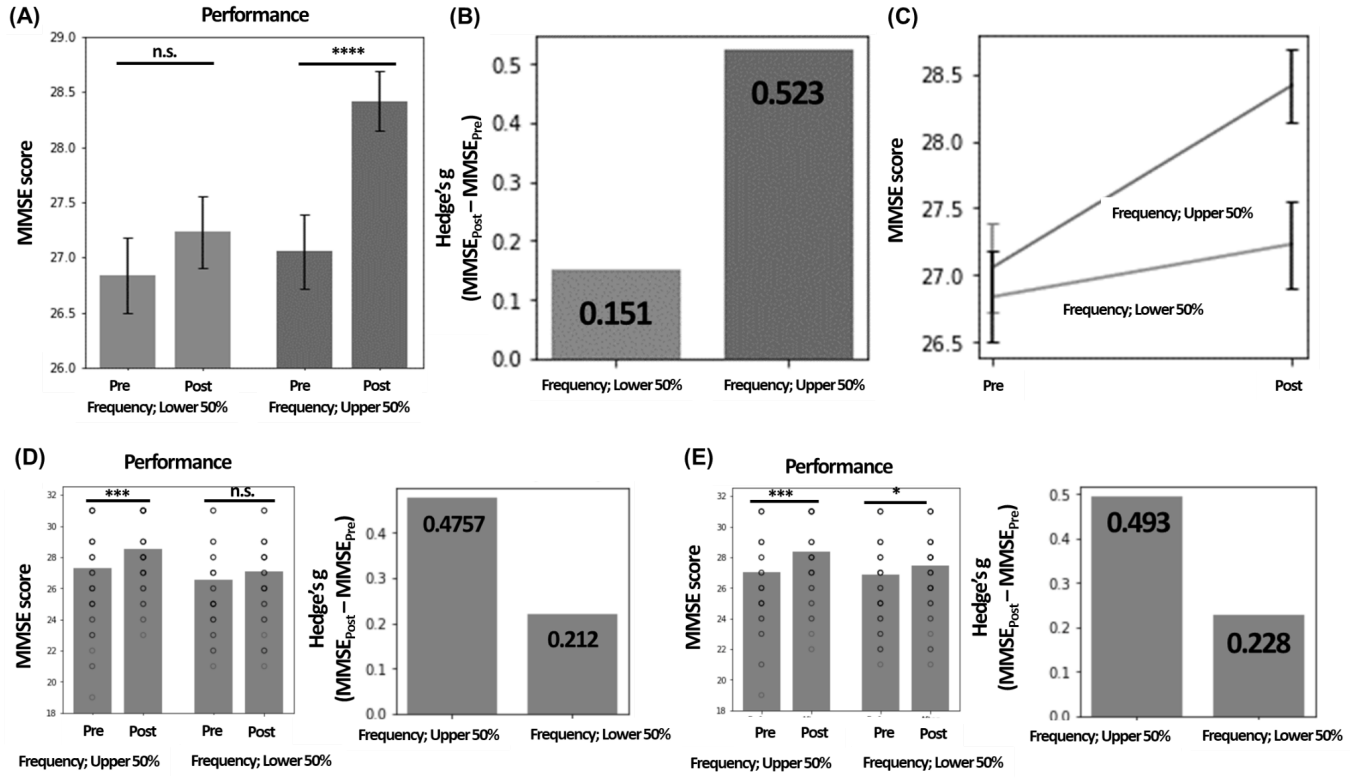

Figure 4. Performance depending upon the frequency to use *Care-and-Cure*. We divided the subjects into two groups based upon the amount of time to use *Care-and-Cure:* we categorised subjects in the lower 50 percentile of the amount of time to use into a lower 50% group, and an upper 50% otherwise. **(A)** Changes in MMSE score of the two groups on average. The more the subject uses *Care-and-Cure*, the higher effect on the improvement exhibited. The upper group showed a significant increase in MMSE score after using more time (paired *t*-test; $p < 0.0001$) while the lower group showed statistically no changes. **(B)** The Effect size. An medium effect size was observed in the upper group. **(C)** Interaction effect. **(D)** In *Sammy* case: changes in MMSE score of the two groups on average (left) and the effect size (right). The upper 50% means subjects in the higher 50 percentile in the amount of time to use *Sammy*, and the lower 50% otherwise. **(D)** In *Smart masil bang* case: changes in MMSE score of the two groups on average (left) and the effect size (right). The upper 50% means subjects in the higher 50 percentile in the amount of time to use *Smart masil bang*, and the lower 50% otherwise.

Table 1. Results on the non-cognitive capacity - a degree of perception on social support, a degree of willingness to participate and emotional relief

N=134

Category		pre(n=134)	post(n=134)	*t*	*p*
		M(SD)	M(SD)		
Social Support	Emotional/ Informational Support	30.22(7.02)	34.09(5.41)	−6.484***	0.000
	Tangible Support	15.2(3.78)	16.28(3.07)	−3.392***	0.001
	Affectionate Support	10.81(2.85)	11.88(2.56)	−4.314***	0.000
	Positive Social Interaction Support	15.21(3.76)	16.43(2.99)	−3.906***	0.000
Engagement	behavior	10.36(3.75)	10.49(3.61)	0.318	0.751
	cognition	11.29(3.57)	12.1(3.34)	2.180*	0.031
	affect	9.92(4.01)	10.81(3.90)	2.059*	0.041
Depression	SGDS	1.93(2.32)	2.46(2.76)	2.856**	0.005

*p < .05, **p < .01, ***p < .001