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Shorter Version of the Brain Assessment Is Suitable for Longitudinal Public Cognitive Evaluations

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Keywords
Brain Assessment · Short version · Correlation · Cognitive decline

Abstract
Introduction: We have developed an online cognitive test (Brain Assessment [BA]) which exhibits moderate correlations with established neuropsychological tests. We made a short version of the BA that requires only 10 min and investigated correlations with the original version. ***Participants and Methods:*** Three hundred and twenty-three subjects (26–82 years old, mean age 41.9 years) were recruited via the internet and performed the original version of the BA online, and, for the analyses of the original and short version, the results of the whole and of the first 2 min were utilized, respectively. Correlations were evaluated between both versions, and 144 subjects agreed to be interviewed about BA utilization. ***Results:*** Correlations between the short and original versions of the BA were strong (memory of numbers, r = 0.72: total, r = 0.73) or moderate (memory of words, r = 0.66; visuospatial, r = 0.42; working memory, r = 0.53; judgment, r = 0.54). We found a strong negative correlation between the "memory of words" subtest and age (short version, r = −0.85; original version, r = −0.88). Regarding the interview, most wanted to be assessed by the short version every year. In the case of a concerning score, they would then want to be examined by the original version of the BA and/or more specific neuropsychological tests. ***Discussion:*** We found that the short and the original versions of the BA exhibited strong correlations, and the correlation coefficients between age and subtest scores were almost the same between the two versions. ***Conclusion:*** The short version of the BA will be useful to perform cognitive assessments in the clinic.

Introduction

There are several problems with standard in-person neuropsychological assessments, such as habituation, commitment of human resources, lack of cross-sectional evaluation, and difficulty of in-person assessments under societal conditions during the era of COVID-19. Thus, we developed an online cognitive test (the Brain Assessment [BA]) that covers five fields: number memory, word memory, mental rotation, working memory (N-back test), and judgment [1]. The N-back test was first repre-

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Table 1. Mean CSs of the short version of the BA by age in 5- or 10-year increments

Age	Subject numbers	Memory		Visuospatial	Working memory	Judgment	Total
		numbers	words				
	m/f	m/f	m/f	m/f	m/f	m/f	m/f
25–30	37/37	73.3/76.9	67.1/66.2	61.8/55.6	65.2/65.1	69.0/60.1	67.3/64.8
31–35	29/37	71.8/73.5	65.8/68.8	67.1/54.6	67.3/60.1	73.3/62.1	69.1/63.8
36–40	26/45	75.4/10.5	69.7/63.5	65.5/53.6	63.1/62.7	68.9/60.3	68.5/62.1
41–50	14/17	73.8/63.5	67.0/61.2	68.6/51.1	68.1/59.4	68.9/56.8	69.3/58.4
51–60	15/19	65.2/60.5	48.8/59.2	58.9/55.8	61.8/65.5	66.5/50.9	60.2/58.4
61–70	12/14	61.3/53.5	53.0/55.1	62.7/47.8	65.0/53.0	57.7/49.9	59.9/51.9
71–80	11/9	52.4/58.5	49.8/48.7	44.2/39.5	50.0/58.4	51.3/51.7	49.5/51.4
(81–85)	(0/1)	(/15.0)	(/34.0)	(/37.0)	(/38.0)	(/34.0)	(/31.6)
Total[a]	144/179	65.9/65.3	58.2/60.4	60.3/51.1	62.3/60.6	63.6/56.0	62.1/58.7

CS. cognitive score; f, female; m, male. [a] Total mean values did not contain subjects over 80 years of age.

sented by Kirchner [2]. In this test, the subject is presented with a sequence of stimuli and is required to do some operation about the current stimulus related to the one from *n* steps earlier in the sequences. The load factor *n* can be adjusted to make the task more or less difficult. The cardinal features of the BA include five different versions to avoid habituation, conciseness (30 min), an automated scoring system, easy online access to mitigate risk of COVID-19, and a base data set based on a large population of 5,000 subjects with a wide age range (40–89). The contents of the questions of the five versions were similar, and the differences in the difficulty levels among these versions were standardized by use of a cognitive score (CS) specified in our previous paper [1]. We found that the BA displayed moderate correlations between established neuropsychological tests [3] such as the Mini-Mental State Examination (MMSE) [4] and the Raven's Colored Progressive Matrices (RCPM) [5] for intellect, memory, visuospatial function, and frontal lobe function.

One of the most important characteristics of the BA is that it can reveal not only cognitive state but also longitudinal changes in cognitive function. The results of the BA can be described as abnormal if the longitudinal change is worse than the normal inclination, even if the absolute score itself is within normal limits. By repeating this test over several years, a subject can determine the degree of their cognitive decline, and in cases where the declination is worse than a normal trajectory, BA performance may promote an improvement in lifestyle and related diseases [3]. Therefore, we expect that the BA is suitable to be carried out during annual health checks. When we attempted to utilize the BA at a health center, three concerns arose, including a lack of time for completing the assessment. At the time of the health check, participants have to undergo several kinds of examinations, including measurements of visual acuity, hearing, height, and body weight, in addition to electrocardiograms, chest X-rays, and other tests. They are so busy that they do not have enough time to perform the BA, which requires almost 30 min. Lack of space was another concern. In order for participants to perform the BA, many personal computers are needed, although space is limited in the health center. Finally, it is impossible to reliably ascertain a participant's performance at home. We had considered having individuals perform the BA at their home beforehand, but we realized that we could not determine if the participant performed the test reliably.

In order to solve these problems, we developed a short version of the BA that can be performed easily. The original version consists of five subtests, each of which takes 5 min [1]. Each test of the short version takes 2 min, such that it needs only 10 min to complete. In the current study, we investigated correlations between two versions of the BA and interviewed participants regarding the desired utilization of the short version in the clinical setting.

Subjects and Methods

Subjects

We recruited participants via the internet over a 1-week period. The BA was made under the estimation that the subjects performed the test using digital devices. We may say that it is reasonable to recruit the subjects who would have the skill for digital de-

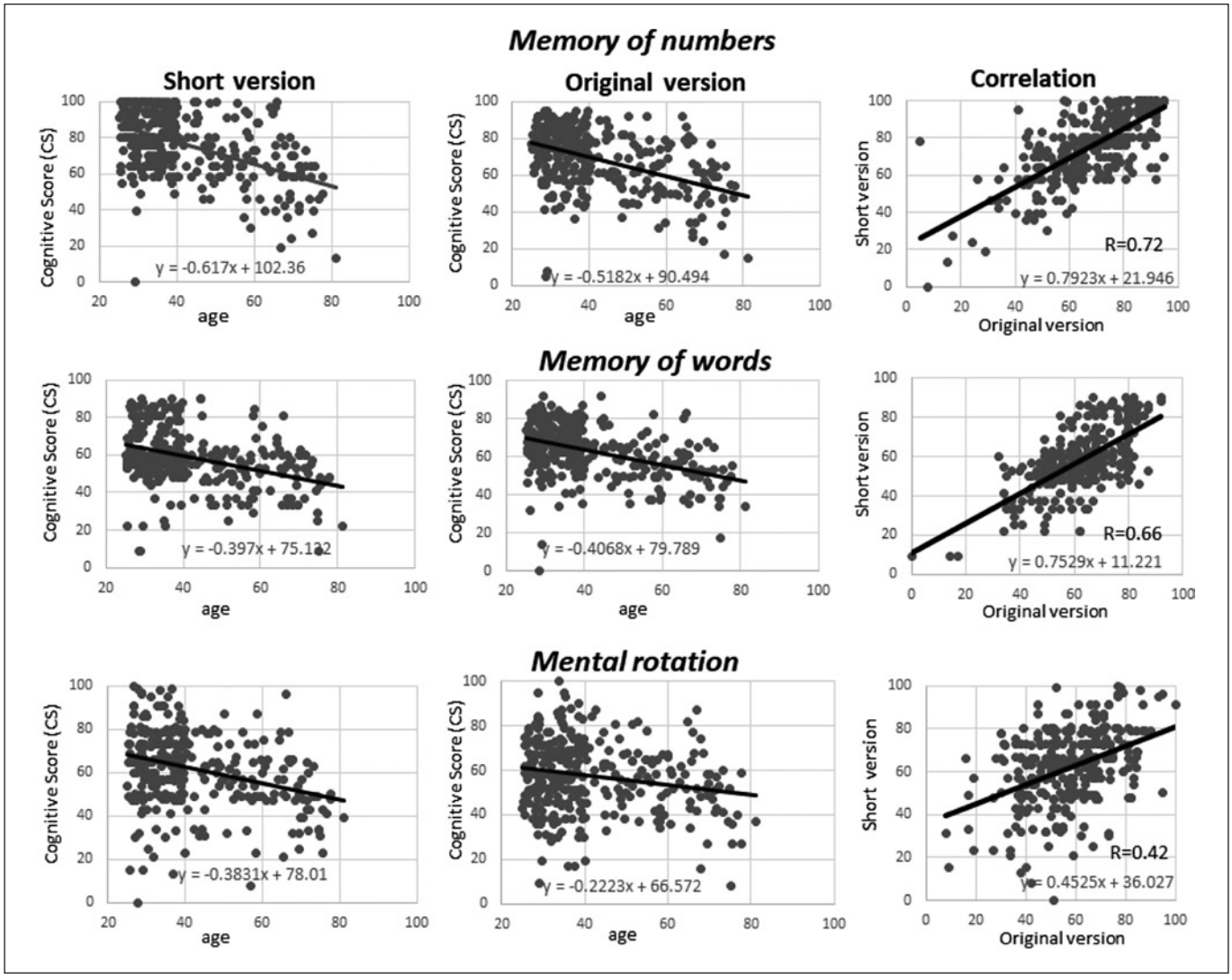


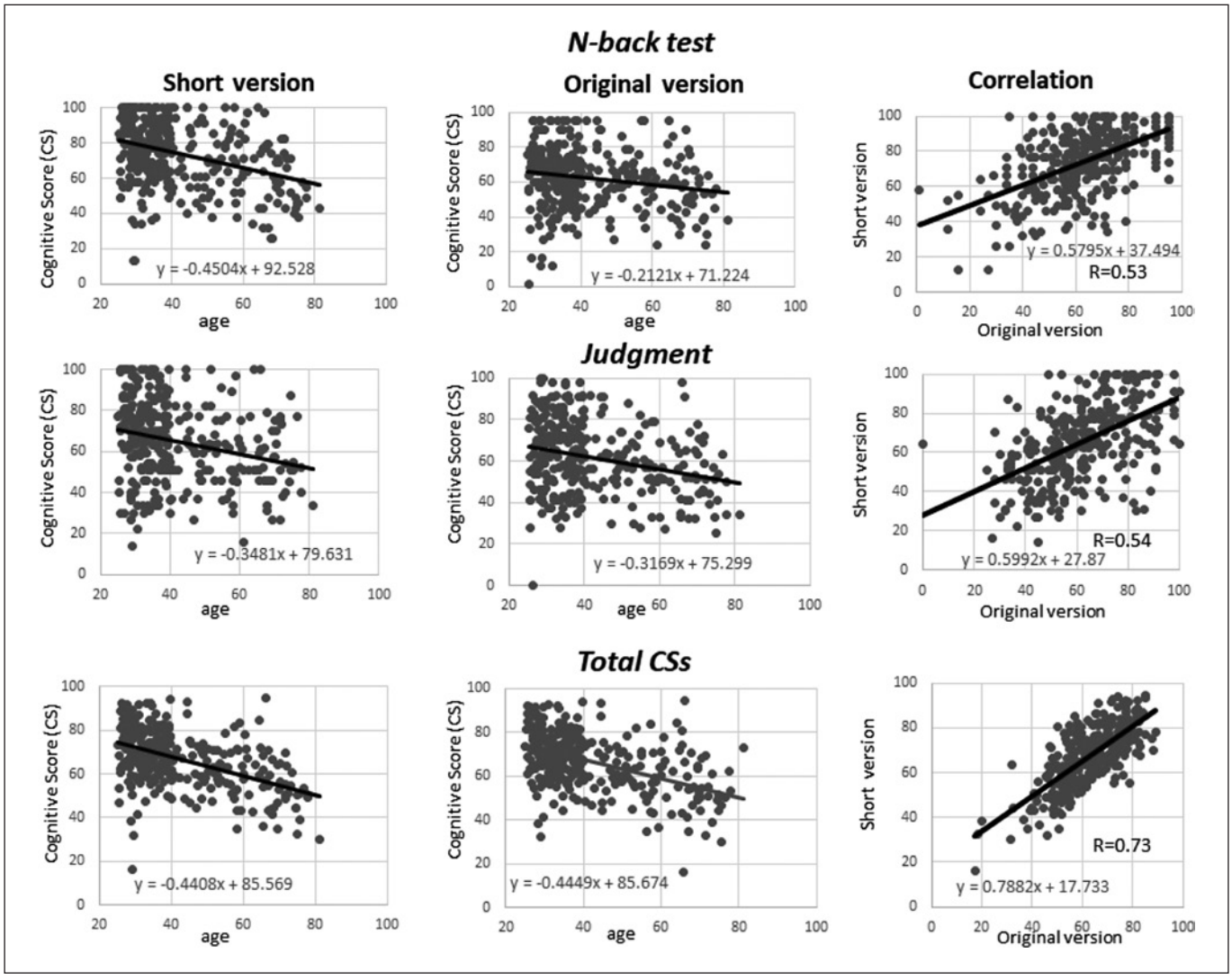
Fig. 1. Correlations between age and the short and original versions of the BA and correlations between both versions. BA, Brain Assessment; CS, cognitive score.

(Figure continued on next page.)

vices. We announced this study by sending a direct e-mail to around one million adults who had a SAISON credit card, issued by the parent company of the Research Institute of Brain Activation. Three hundred and twenty-six participants were recruited to perform both the original and short version of the BA online. As mentioned below in detail, the contents the short and original version were the same. Three participants did not finish the BA correctly; thus, the data from a total of 323 subjects (male 144, female 179; 26–82 years old, mean age 41.9 years) were utilized for statistical analyses. The number of subjects from each age range is shown in Table 1.

Short Version of the BA

The contents of the short version of the BA were the same as those of the original version [1]. Many questions were prepared, and the subjects were required to answer them as many as possible during the time set in advance. The level of the cognitive function including the psychomotor speed and mental set change of each subject might be reflected to the number of the questions to which the subject could answer in the limited time. Participants carried out the original version of the BA online. For the analyses of the original and short version, the results of the whole and of the first 2 min were utilized, respectively. Each subtest of the original version required 5 min, while the short version requires 2 min. So, subjects will be able to perform the short version of the BA in around 10 min. According to the procedures of the original version, we standardized the raw scores (CSs) using the mean and standard deviation (50 and 16, respectively) and then calculated the mean CS for each sex and age. For more details about the calculation of CSs, please see our previous papers [1, 3].



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Interviews to Subjects

After taking both versions of the BA, subjects were asked about the utilization of the BA as follows: (1) which version of the BA is better?, (2) why do you think so?, and (3) during health checks, what is the best way to utilize both versions of the BA?: namely, use the original version every year or use the short version every year and if there is something amiss, then perform the original version of the BA and/or close neuropsychological examinations. One hundred and forty-four subjects (male 58, female 86; mean age 40.5 ± 14.1 years) answered the questions.

Statistical Analyses

According to our previous experiments [1, 3], we calculated the mean CS of the short and the original version of the BA for each sex and age, plotted the relationships between ages and mean CSs in figures, and calculated a formula for cognitive changes. Then, we calculated the correlation coefficients of CSs between two versions of the BA. The data were distributed parametrically; thus, Pearson's correlation coefficients were used. The results were interpreted as indicative of small (0.0–0.2), fair (0.2–0.4), moderate (0.4–0.7), and strong (0.7–1.0) associations. We regarded the results as significant if the p value was under 0.05. All statistical analyses were performed using IBM SPSS Statistics 23 software.

Results

Mean CSs from the short version of the BA are shown in the Table 1. Because the numbers of subjects were small, averages were calculated in 10-year categories for participants over 40 years of age. The number of subjects over 80 was only one, so the results over 80 were omitted in the calculation of total mean values. As a whole, the tendencies were almost the same as the findings of our previous study of the original version [1]. First, the values

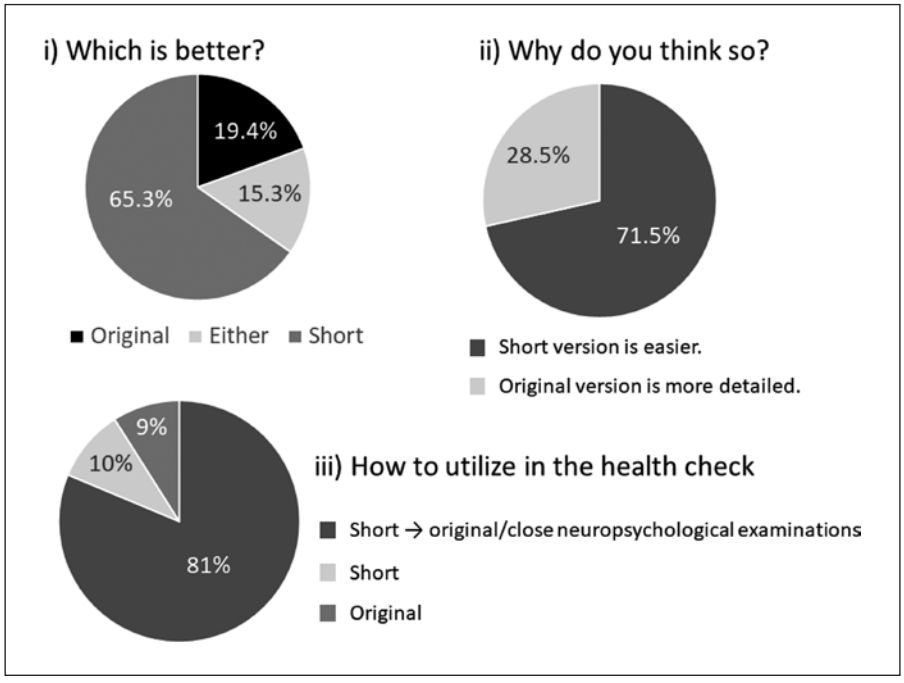

Fig. 2. Interview results regarding the utilization of the short and the original version of the BA. BA, Brain Assessment.

Table 2. Pearson's correlation coefficients between age and the results of the short and original versions of the BA and between the two versions

	Memory		Mental rotation	*N*-back test	Judgment	Total
	numbers	words				
Short version versus age	−0.49	−0.85	−0.32	−0.35	−0.26	−0.48
Original version versus age	−0.45	−0.88	−0.20	−0.38	−0.26	−0.48
Short versus original version	0.72	0.66	0.42	0.53	0.54	0.73

gradually worsened by age. Second, the memory of words was better in females versus males. Finally, female visuospatial ability was worse compared with males.

The results of the statistical analyses are summarized in Figure 1 and Table 2. The correlation coefficients of the short and the original version of the BA against age were similar (Table 2). Both versions showed strong negative correlations in memory of words (short version, $r = -0.85$; original version, $r = -0.88$). The correlation of both versions against age was moderate in memory of numbers (short version, $r = -0.49$; original version, $r = -0.45$) and in the total assessment (short version, $r = -0.48$; original version, $r = -0.48$). As for other subtests, the coefficients revealed fair correlations across both versions (visuospatial, short version $r = -0.35$, original version $r = -0.20$; working memory, short version $r = -0.35$, original version, $r = -0.38$; judgment, short version, $r = -0.26$; original version, $r = -0.26$). The correlations between the short and the original version of the BA were also strong (memory of numbers, $r = 0.72$: total assessment, $r = 0.73$) or moderate (memory of words, $r = 0.66$; visuospatial, $r = 0.42$; working memory, $r = 0.53$; judgment, $r = 0.54$) (Fig. 1; Table 2).

The results of the subject interview are presented in Figure 2. For the first question, 65.3% of subjects replied that the short version is better than the original one. In the second question, they regarded that each version has its own advantages: the short version has good facility in usage, while the original version can provide a more detailed assessment. For the last question, most subjects wanted to be assessed by the short version every year, and if the cognitive changes are worse than that by normal aging, then examined by the original version of the BA and/or additional neuropsychological tests.

Fig. 3. Tablet- and printer-based device incorporating the short version of the BA. Behind the tablet, there is a panel on which the information about the device is described. The description of the panel includes the title of the assessment, necessary time to do, how to perform these tests, and the name of the supplier. On the screen, the five subtests are represented with brief explanations about each test, and the subject can start each test by touching the name of the subtest. After the assessment, results and additional information can be printed depending on the characteristics of the institution, including a URL code introducing detailed neuropsychological and neuroimaging assessments, the name and the telephone number of the institution. This small device can be set in a small space in the waiting room of the health center. BA, Brain Assessment.

Discussion

We investigated correlations between age and both the short and original versions of the BA, as well as correlations between the two versions. The results of the present study are summarized as follows: (1) there were strong correlations between the short and the original versions of the BA, (2) the correlation coefficients between age and the subtests were almost the same between the two versions, (3) for "memory of words," both versions exhibited strong correlations, (4) in the subject interview, many thought that the short version was better because of its utility, and (5) the combination of the two BA versions is thought to be useful for annual health checks. Based on these findings, we believe that the short version of the BA is relevant to the assessment of cognitive function, similar to the original version.

We believe that the short version of the BA would be useful in actual clinical settings. The primary problem with the original version is a longer administration time for the purpose of general health checks. The short version takes only 10 min, and individuals can perform it during the waiting period before a health check. In order to solve a second problem, namely, the lack of space, we prepared a tablet version of the short version (Fig. 3). In this case, subjects answer by touching the display screen, and their results are printed out by a small printer beside the tablet. The report sheet contains the results of the tests along with advice and contact information such as the hospital telephone number. If necessary, subjects can receive the original version of the BA and/or neuropsychological tests for more detailed assessments. Along with the advantage of the tablet version, we have to mention its disadvantage in the clinical settings. There will be many distractors in the waiting room of the health check center, for example, others' voices, sound of the television, and in some cases, the back ground music. It is recommended that the tablet is set at the relatively quiet place as the corner of the room, and the subject will concentrate on the test eagerly in order to get the good results about his/her own cognitive function. But we cannot completely deny the possibility that the distractors in the room might affect the results of the tests.

Both versions exhibited wide variation in the results for the mental rotation, N-back test, and the judgment test. This phenomenon suggests that visuospatial ability and working memory are fairly different depending on individuals. As such, in order to assess age-based declines of cognitive function correctly, current results as well as alterations over several years are important, as closely explained in our previous paper [1]. The results of the patient interview suggest that it is necessary to distinguish the utility of each version of the BA depending on the situation. We believe that it is appropriate to use the short version at annual health checks, and if alterations of cognitive function are worse than what is expected by normal aging, the subject should receive more detailed assessments by in-person neuropsychological examination and/or online assessments by the original version of the BA.

This study has several limitations. First, the number of participants was small. This study examined the results of 323 participants, while that of the original version studied 5,000 individuals. However, the strong correlation between the two versions suggests the validity of the short version. Second, in-person assessments using general neuropsychological tests were not performed in the present study due to the ongoing outbreak of COVID-19. Lastly, we did not perform longitudinal assessments, which is one of the advantages of the BA. Despite these limitations, we can reasonably conclude that the short version of the BA, like the original one, can determine cognitive function correctly.

Statement of Ethics

This study received approval from the Advanced Institute of Industrial Technology Research Ethics Committee (Approval No. 19009) and was conducted in accordance with the Helsinki Declaration of 1975. All of the participants provided informed consent in writing or online on the site used to run the assessment and collect data.

Conflict of Interest Statement

The Department of Dementia and Neuropsychology, Master Program of Innovation for Design and Engineering, Advanced Institute of Industrial Technology, was established using donations provided by the Research Institute of Brain Activation.

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Author Contributions

Masayuki Satoh: design of the study, interpretation of data, and writing the manuscript. Ken-ichi Tabei: interpretation of data and revision for important intellectual content. Makiko Abe: acquisition and interpretation of data. Chiaki Kamikawa: acquisition and interpretation of data. Saiko Fujita: analyses of data. Yoshinori Ota: design of the study and acquisition of data.

Data Availability Statement

All data analyzed during this study are included in this article. Further inquiries can be directed to the corresponding author.

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