RBANS form equivalence in specific English language regions

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The Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) is a quick assessment of cognitive function with four equivalent forms, validated in the United States. This permits assessment of cognitive decline or improvement. Equivalent forms reduce some repeat testing effects in longitudinal assessments. An important incidental finding in a New Zealand controlled trial utilising the RBANS as a primary outcome measure, was that form A and form B were different in immediate memory scores. The controlled trial was negative for changes in all RBANS items. Although validating the RBANS in our cohort was not the purpose of this study, the difference found between form A and B was significant. The RBANS form A 'story memory' item contains a phrase that is unusual in New Zealand speech, and could explain the observed discrepancy between the forms. Although the forms have been validated previously, different English language regions should check for any phrasing that is unusual if not previously validated in the local population.

Keywords: *Repeatable Battery for the Assessment of Neuropsychological Status; RBANS; Memory; Repeated Testing; Longitudinal Assessment*

Introduction

The Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) (Randolph, 1998) is a brief test designed to measure attention, language, visuospatial ability, and immediate and delayed memory. It takes less than 30 minutes to administer, and is sensitive to mild impairments in these domains. There are 12 subtests, which map onto five neuropsychological domains.

A key advantage of the RBANS is that it has four equivalent forms (Randolph, 1998), which are designed to make it easier when administering repeated assessments. The multiple forms use the same testing structure but change the content of the trials, e.g. the subject is asked to memorise a different list of words in form A and form B.

Repeated testing in psychometrics can result in inflated scores through a number of mechanisms. Subjects may remember elements of the test from previous sessions, and so be able to focus more attention on items they haven't remembered, which are referred to as content-based practice effects (Miller et al., 2009). Also, subjects can develop more efficient cognitive strategies to complete some tests (Rozencwajg & Corroyer, 2001), which are called process-based practice effects. The use of multiple equivalent forms can reduce content-based practice effects by presenting different stimuli that test the same construct. Doing this can mostly eliminate an increase in scores from practice effects (Calamia, Markon, & Tranel, 2012). However, process-based practice effects cannot be controlled for by using multiple equivalent forms.

The RBANS A and B forms have been tested in an equivalency study in the United States (Randolph, 1998). The study was performed in 100 individuals with a counterbalanced design so that the same numbers of participants started on both forms. The maximum mean difference in the indices between form A and form B was 4.5 points in the delayed memory index (correlation coefficient 0.64). The mean difference in the immediate memory index was smaller than this (correlation coefficient 0.68 corrected). No additional studies investigating the equivalence of forms A and B (English version) were found in the literature.

We used the RBANS as a primary outcome measure to investigate change in memory in a randomised placebo-controlled trial of EEG biofeedback source-localised to the Posterior Cingulate Cortex (PCC). EEG biofeedback is a training technique where participants take voluntary control of aspects of the EEG rhythm (Masterpasqua & Healy, 2003). The study was carried out in adults with memory symptoms and a RBANS immediate memory score of less than 90 (Galt, 2019).

METHODS

Participants

Participants were recruited from the general population in Dunedin, New Zealand, through public noticeboard advertisements, direct approach to community groups of older adults, and sign-up sheets at community events run by the Brain Health Research Centre, University of Otago. Participants were required to be aged over 40 years with no history of dementia or other neurological disease. Those meeting these criteria were

Table 1. Average demographic characteristics of study participants

Category	Total Sample	Group A	Skewness, Kurtosis	Group B	Skewness, Kurtosis	*p*-value (A vs B)
N of volunteers	223	112		111		
Age (range)	*M*=65.2 (40-92)	*M*=64.9 (44-89)	-.1, -.4	*M*=65.5 (40-92)	-.2, -.2	*p*=.598
N of women (%)	142 (63%)	77 (68.8%)		65 (58.6%)		
Years of education	*M*=15.3 (*SD*=2.58)	*M*=15.3 (*SD*=2.70)	-.2, -.7	*M*=15.2 (*SD*=2.47)	.3, -.1	*p*=.562

asked to take the RBANS to be assessed for inclusion in the biofeedback trial. Recruitment was not specifically targeted at people concerned about their memory. Participants with mild anxiety and depression were included, but were excluded if they were currently taking anti-depressant or anxiolytic medications. Those who scored 90 or below on the immediate memory index of the RBANS were included, those who scored above 90 were excluded from the EEG biofeedback trial, but their RBANS score and an initial EEG were retained.

Table 1 describes the basic characteristics of participants in the initial screen using the RBANS. Participant characteristics were compared using t-tests.

Survey

The RBANS (Randolph, 1998) was used as the primary measure. The test was administered in its entirety, however, this analysis mainly pertains to the immediate and delayed memory components of the test, described below.

The subtests for the immediate and delayed memory indices comprise: (i) Word List Immediate Recall. The test administrator reads out the list of ten words at a rate of one word per second. The participant then repeats as many of the words as he/she can remember. This is repeated over four trials with the words in the same order each time. The score for this section is the total number of words remembered across all four trials. (ii) Story Memory Immediate Recall. The participant listens to a story comprising of two sentences over approximately 20 seconds. The participant subsequently recites the story as exactly as possible. The score is based on the recall of 12 details of the story. (iii) Figure Copy. the participant is asked to copy a figure. Ten points are scored for the accuracy of the features, and ten points are scored for the accuracy of the spatial relationships between the features. (iv) Word List Delayed Recall. The participant is asked to recall (without prompting) the same list as in the immediate recall and is scored on the number recalled. (v) List Recognition. A list of 20 words is read out, ten of which are contained in the word list recall task. The subject is asked to identify which words were also on the immediate recall list. Participants are scored for correctly stating that a word is on the list, and correctly stating that a word is not on the list. (vi) Story Memory Delayed Recall. The participant is asked to recall, with a single prompt, the story from the immediate story recall task. Participants are scored on each of the 12 details. (vii) Figure Recall. The participant is asked to re-draw from memory the figure from the figure copy. Ten points are scored on the accuracy of the features of the figure, and ten points are scored for the spatial relationships between the features. The Immediate Memory Index score is generated from a table based on the participant's age, word recall score, and story recall score. The Delayed Memory Index is generated from a table based on the participant's age, the list delayed recall, story delayed recall, and figure delayed recall scores, and the list recognition score.

The subtests for the Language Index comprise: (i) Picture naming. Ten pictures are shown, and the participant is required to name each of them (for example, yacht, camel, lion). (ii) Semantic fluency. The participant is required to name as many members of a category as they can in one minute, for example, name as many animals as they can. The Language Index is generated from a table based on the participant's age and the two Language Index sub-scores.

Procedure

Participants were screened with RBANS form A or form B, using blocked (balanced) randomisation. Participant groups are referred to by the letter of the form they started on, i.e. 'group A' and 'group B'. Participants who were included in the biofeedback trial (those who initially scored below 90 in the Immediate Memory Index) had three RBANS assessments: A-B-A or B-A-B. The first was at study entry, the second after the biofeedback training at five weeks, and the third a further six weeks following the end of the training.

Groups A and B were further blocked randomised independently into the trial arms of the EEG biofeedback study: a broadband feedback group (training EEG theta and alpha up, beta and gamma down), narrowband feedback group (training alpha up and beta and gamma down), and placebo feedback group (visual stimulus randomly generated). Each participant underwent 15 sessions of EEG biofeedback training over four weeks. During the training, EEG was analysed in real time to derive a source localised signal from the PCC, specifically the relative EEG frequency power ratios, which were displayed visually as the height of a bar on a laptop, and participants were asked to keep the bar in the top half of

the laptop screen. The results of this trial showed that biofeedback did not alter the memory scores of the participants, which meant that performance of the RBANS could be carried out at all three time points. Further details of this study are available (Galt, 2019).

The study was approved by the University of Otago Human Ethics Committee. Approval to conduct the study in the Southern District Health Board locality was obtained through Health Research South. The trial was registered with the Australian and New Zealand Clinical Trials Register, registration number ACTRN12616001731482.

Statistical Analysis

Skewness and kurtosis were calculated to assess the normality of the underlying data. The difference between the groups at baseline was assessed using independent sample t-tests, using a Bonferroni adjusted significance level of 0.003, to correct for multiple comparisons. The difference between the initial score and the score at the initial follow up were compared using independent sample t-tests, as was the comparison between the initial score and the score at the delayed follow up. A Bonferroni adjusted significance level of 0.003 was used for these comparisons as well. Where assumptions of normality were not met, a Wilcoxon sign rank test was performed, with p = 0.003 as the level of significance adjusted for multiple comparisons.

RESULTS

A total of 223 volunteers took part in an initial screening session, 142 women and 81 men. Of these, 68 (31 women and 37 men, mean age 67.6) scored below 90 on the RBANS in the immediate memory index score and were selected. Of these 68, 53 (22 women and 31 men, mean age 67.8) completed the randomised EEG biofeedback trial and three RBANS assessments.

Table 2. Average baseline RBANS scores of all participants

Category	Total Sample Mean (*SD*)	Skewness, kurtosis	Group A Mean (*SD*)	Skewness, kurtosis	Group B Mean (*SD*)	*p*-value (A vs B)
List Learning	27.2 (4.91)	-.8, .8	26.7 (5.13)	-.6, 1.0	27.7 (4.63)	*p*=.189
Story Learning	16.2 (3.75)	.0, -.6	15.0 (3.83)	-.8, .6	17.4 (3.25)	*p*<.001*
Figure Copy	18.7 (1.56)	-1.9, 4.6	18.9(1.45)	-1.2, 1.6	18.5 (1.64)	*p*=.75
Line Orientation	17.4 (2.74)	-.9, .3	17.4 (3.25)	-2.4, 9.2	17.4 (3.01)	*p*=.744[a]
Picture Naming	9.6 (0.86)	-2.0, 5.7	9.5 (0.73)	-7.2, 64.5	9.7 (0.95)	*p*=.006[a]
Semantic Fluency	21.2 (5.02)	-.0, -.2	22.8 (4.95)	.9, 1.1	19.7 (4.60)	*p*<.001*
Digit span	10.7 (2.39)	.5, .9	10.6 (2.2)	.3, -1.0	10.6 (2.57)	*p*=.643
Coding	45.4 (9.93)	.1, .1	45.9 (10.1)	-.4, .4	44.8 (9.73)	*p*=.388
List Recall	5.8 (2.28)	-.6, .3	5.5 (2.28)	-.6, -.4	6.1 (2.25)	*p*=.051
List Recognition	19.1 (1.36)	-2.1, 5.8	19.1 (1.41)	-2.7, 13.0	19.2 (1.30)	*p*=.990[a]
Story Recall	8.6 (2.63)	-.7, .0	7.8 (2.65)	-1.3, 2.3	9.5 (2.35)	*p*<.001*
Figure Recall	14.4 (93.81)	-1.0, .9	14.4 (4.14)	-1.3, 2.9	14.4 (3.42)	*p*=.670
Index						
Immediate Memory	98.4 (14.69)	-.4, .3	94.4 (14.67)	-.6, .4	102.2 (13.57)	*p*<.001*
Language	101.6 (11.39)	-.4, 1.3	104.1 (11.81)	.6, 1.7	99.0 (10.36)	*p*=.001*
Delayed Memory	101.4 (14.43)	-1.3, 3.0	99.6 (14.68)	-1.1, 2.7	103.3 (13.92)	*p*=.041
Total Scale Index	103.5 (13.48)	-.3, .2	103.2 (14.08)	.0, .9	104.0 (13.92)	*p*=.748

Notes: **p*<0.003 by independent samples t-test, [a] *p*-value calculated by Mann-Whitney U test

Table 3. Average baseline scores of participants who scored 90 or below on the Immediate Memory Index of the RBANS.

Category	Qualifying participants Mean (*SD*)	Group A Mean (*SD*)	Skewness, Kurtosis	Group B Mean(*SD*)	Skewness, Kurtosis	*p*-value (A vs B)
Age	67.8 (10.18)	67.9 (9.99)	-.1, .0	67.8 (10.50)	.1, .4	*p*= .97
N of Women (%)	22 (41.5%)	13 (39.4%)		9 (45.0%)		*p*= .69
Years Education	14.1 (2.43)	14.3 (2.33)	-.3, -.7	13.7 (2.55)	.9, .6	*p*=.39
List Learning	22.5 (4.82)	22.7 (4.94)	-.5, -.4	22.1 (4.58)	-.5, -.74	*p*=.65
Story Learning	12.5 (2.90)	12.0 (2.84)	.2, .6	13.4 (2.78)	-.0, -.1	*p*=.09
List Recall	4.0 (2.20)	4.2 (2.22)	-.5, -.6	3.7 (2.17)	.6, .1	*p*=.35
List Recognition	18.3 (1.85)	18.5 (1.69)	-1.9, 5.2	18.1 (2.07)	-2.0, 5.8	*p*=.43
Story Recall	6.2 (2.64)	5.9 (2.51)	-.0, .0	6.7 (2.78)	-.7, .1	*p*=.31
Figure Recall	12.0 (4.50)	12.7 (4.44)	-.9, .9	11.0 (4.40)	-1.0, .6	*p*=.18
Index						
Immediate Memory	80.9 (9.37)	80.2 (9.70)	-1.8, 2.7	82.0 (8.70)	-.9, -.2	*p*=.50
Delayed Memory	88.7 (14.39)	90.1 (13.99)	-1.7, 3.7	86.5 (14.77)	-1.4, 3.4	*p*=.38
Total Scale Index	90.2 (9.98)	90.9 (9.94)	-1.5, 3.5	89.0 (9.92)	-0.3, 0.3	*p*=.50

Table 4. Differences in average RBANS score at first follow up between Groups A and B

RBANS Subtest or Index	Group A assessment two score Mean (*SD*)	Gp A change vs baseline Mean (*SD*)	Skewness, Kurtosis	Group B assessment two score Mean (*SD*)	Gp B change vs baseline Mean (*SD*)	Skewness, Kurtosis	*p*-value of change vs baseline (A vs B)
List Learning	25.2 (4.52)	2.5 (3.93)	.5, -.0	22.6 (5.08)	0.5 (3.79)	.4, -.5	*p*=.091
Story Learning	16.0 (3.79)	4 (3.88)	-.3, .8	12.3 (3.95)	-1.1 (4.41)	.4, -.4	*p*<.001*
Picture Naming	9.8 (0.52)	0.6 (0.89)	1.1, 1.4	9.7 (0.46)	0.1 (0.70)	-.1,-.9	*p*=.067
Semantic Fluency	18.7 (4.44)	-1 (4.26)	-.9, 1.0	20.6 (4.57)	3.7 (5.18)	-.7, 1.3	*p*<.001*
List Recall	5.4 (2.40)	1.2 (2.08)	.0, 2.9	3.2 (1.66)	-0.5 (2.20)	-.7, -.4	*p*=.023
List Recognition	18.2 (2.26)	-0.3 (2.46)	.5, 2.8	18.3 (2.10)	0.2 (1.25)	.5, -.1	*p*=.561
Story Recall	8.7 (2.48)	2.8 (2.39)	-2.6, 12.0	6.1 (3.13)	-0.6 (2.82)	.3, -.7	*p*<.001*[a]
Figure Recall	12.7 (4.09)	0.1 (3.15)	-.0, .3	11.0 (4.25)	0.1 (3.28)	.2, -.8	*p*=.952
Index							
Immediate Memory	95.8 (13.07)	15.5 (10.58)	-.34, .48	82.3 (12.32)	0.2 (12.56)	.1, .7	*p*<.001*
Language	96.9 (10.76)	0.2 (12.05)	.6, 2.3	101.2 (7.44)	7.8 (10.53)	-.9, 1.0	*p*=.005
Delayed Memory	96.2 (15.36)	6.2 (9.04)	-.0, .7	87.3 (16.04)	0.8 (10.33)	.5, -.1	*p*=.056
Total Scale Index	95.4 (10.26)	4.5 (7.00)	.0, .7	90.3 (12.43)	1.3 (9.63)	-.0, -1.1	*p*=.244

** p=<0.003 by independent sample t-test, [a] p-value calculated by Mann-Whitney U*

Table 2 gives the average RBANS index scores for the initial testing of all 223 participants who underwent screening and for participants who were initially tested with form A (group A) or form B (group B). Statistically significant differences were detected between groups A and B in three out of twelve subtests in initial testing: 'Story Learning', 'Semantic fluency', and 'Story recall'. These map onto a significant point difference in both the Immediate Memory Index and Language Index, with subjects tested on form B scoring 8.8 points higher than subjects on form A ($t(222)=1.902$, $p<.001$), and subjects on form A scoring 5.1 points higher than form B ($t(222)=3.313$, $p<.001$), respectively.

Table 5. Difference in second follow up score between form A and form B

RBANS Subtest or Index	Form A Gp Delayed follow up score Mean (SD)	Change vs baseline Mean (SD)	Skewness, Kurtosis	Form B Gp Delayed follow up score Mean (SD)	Change vs baseline Mean (SD)	Skewness, Kurtosis	*p*-value of change vs baseline difference
List Learning	25.0 (5.39)	2.2 (4.31)	.2, -.2	24.2 (3.92)	2.1 (3.09)	.0, -.5	*p*=.952
Story Learning	15.2 (3.52)	3.2 (2.72)	-.2, -.2	16.0 (4.14)	2.6 (3.39)	-1.0, 1.3	*p*= .501
Picture Naming	9.6 (0.49)	0.4 (0.70)	1.4, 2.7	9.8 (0.40)	0.2 (0.51)	.4, .2	*p*=.523
Semantic Fluency	20.7 (4.46)	1.2 (3.24)	-.3, .7	17.9 (3.90)	1.0 (3.07)	-.2, -.7	*p*=.937
List Recall	4.8 (2.57)	0.5 (1.44)	.4, 1.0	4.3 (2.49)	0.6 (1.66)	-.8, 1.1	*p*=.399
List Recognition	18.6 (1.85)	0.1 (1.63)	.3, .9	18.8 (1.72)	0.7 (1.31)	1.0, 4.3	*p*=.174
Story Recall	7.8 (2.71)	2.0 (2.19)	-.2, .5	8.3 (2.95)	1.7 (2.37)	-1.3, 3.4	*p*=.876
Figure Recall	13.2 (4.35)	0.6 (2.96)	-.2, .5	12.6 (4.62)	1.7 (2.65)	-1.3, 3.5	*p*=.311
Index							
Immediate Memory	93.1 (12.64)	12.8 (10.79)	.4, .5	93.2 (10.89)	11.2 (9.65)	-.1, -.3	*p*=.805
Language	101.8 (8.67)	5.1 (10.69)	.5, 1.4	96.5 (6.22)	3.1 (6.45)	-.1, -.9	*p*=.480
Delayed Memory	96.4 (17.20)	6.3 (11.11)	.4, .8	95.6 (16.51)	9.1 (11.47)	-.0 , 1.0	*p*=.408
Total Scale Index	97.9 (11.40)	7 (8.50)	.6, 1.8	95.3 (10.10)	6.3 (6.59)	-.5, -.9	*p*=.885

Table 3 shows the average baseline RBANS scores for the 53 subjects who completed all 15 sessions of the biofeedback training. In this group who went on to do the biofeedback trial, 33 were screened using form A, and 20 using form B, with no significant differences at baseline. Given the selection criteria for entering this group included a score of less than 90 on the immediate memory index, these two groups were expected to have equivalent scores at baseline. As such, no significant difference between the two groups was found with the average baseline Immediate Memory Index, nor either of the two related subtests.

Table 4 shows assessment 2 RBANS scores, and change from assessment 1, separated by groups A and B. There is a difference from assessment 1 to assessment 2 in the immediate memory index. Group A (assessed on form B at assessment 2) improved 15.5 points at assessment 2 on immediate memory. In contrast, group B (form A at assessment 2) scored 0.2 points higher at follow up (between Groups $t(52)=4.673$, $p<.001$). This is not influenced significantly by the negative trial interventions (Galt 2016). The biggest difference in assessment 1 and 2 between the groups in Immediate Memory subscores was in the 'story learning' component, 5.1 points, ($t(52)= 4.314$, $p<.001$).

Table 5 shows the RBANS groups A and B mean score at delayed follow up, assessment 3, and there were no significant between group differences. Group A had increased 12.8 points in the immediate memory index. Group B increased 11.2 points from baseline. Again, there was no significant influence from the interventions (data not shown, see Galt 2019). The difference between the two groups has disappeared at this time point

DISCUSSION

Overall, in our New Zealand cohort, the immediate memory index RBANS items are more difficult in form A compared to form B. This effect was seen for all who were screened initially.. Because the participants in the biofeedback trial were selected on the basis of their Immediate Memory Score, this meant that the groups were artificially made the same at this time point. Participants who then switch from form A to form B has a big increase in their immediate memory score, specifically on the Story Memory task. Participants who switched from form B to form A had almost no increase at all in their assessment 2 score. These same participants had a large increase in memory score on switching back to form B for assessment 3, in contrast to the participants switching back to form A who did not increase their scores between assessment 2 and 3 as much. Thus, we find a significant difference between the groups at assessment 2, where the participants were assessed on the opposite form they started on, and not at assessment 1 and 3 This suggests that the task in form A may be more difficult for New Zealand participants than the task in form B.

Because the RBANS immediate memory was used as both a screening and outcome measure, this can complicate repeated measures analyses. A 'silver lining', for the purposes of this report, was that our trial interventions were all negative. This allowed data from the 3 arms to be effectively combined and more easily reveals between form differences in immediate memory.

Given that the intervention trial had no effect on the participant's ability measured by the RBANS, changes in score should only reflect practice effects. We would expect therefore that there would be an increase in the Immediate Memory score at each of assessments 2 and 3, but no difference between those who were being assessed on form A and form B. Subjects with assessment 1 with form A had a significantly greater (14 point) increase in immediate memory score at assessment 2, in comparison to participants who started on form B, in contrast to what we would expect. The difference between the form A and B immediate memory reduced at assessment 3, which reflects the participants switching back to the form they were originally tested on. This finding indicates that switching between the forms is what is causing the unexpected finding at assessment 2. An explanation for this is that form A more difficult, and switching between the forms highlights that difference, instead of the scores increasing in parallel as we might expect.

As the form A immediate memory index was 'more difficult', those who were enrolled with form A may have had greater relative ability in the immediate memory task than those screened with form B. This may be an explanation for the size of the difference between form A and form Bat assessment 2.This is because the practice effects were compounding with the fact that the task in form B was easier.

Differences were found in Language Index for participants screened for the trial. However, no differences were found that had reached significance in the group that went on the complete the biofeedback trial. It is unclear from our study what the implication of this result is for repeated testing using the different RBANS forms. A larger study of repeated assessments might find a more subtle difference in the way the Language Index performs between the forms when performing serial tests.

The subjects in our study had a significant 7.8 point difference in the RBANS immediate memory index score between forms A and B for the people who presented for screening into the biofeedback trial. In contrast, the form equivalency study presented by the test designers found only a 0.2 point difference (Randolph, 1998). This equivalency study was performed in the United States, and there are several reasons why a form effect could exist our cohort and not in the United States cohort. Word frequency and phrasing varies between regions. Memory tests, such as the list memory task in the RBANS, are impacted by the frequency of words in the background population (Hulme et al., 1997).

Perhaps crucially, the story memory item in form A had a phrase referring to a '3 alarm fire'. Describing the intensity and containability of a fire in a multiple-alarm categories is commonly used in the USA and Canada, but is not a common idiom in New Zealand. It was observed by the tester that participants had a lot more difficulty remembering this phrase and the content after it, compared to the phrase in the corresponding story in form B. We hypothesize this phrase could have interrupted memory encoding for the rest of the story as subjects struggled to interpret this. Future studies in this area may be an item-by-item analysis to confirm this hypothesis.

A limitation of this study is that all participants were adults over the age of 40, and all were drawn from one population centre withing New Zealand. Therefore, this finding may not be applicable in younger adults, or those drawn from other population centres.

Linguistic features of the tasks may mean that there is not complete equivalence of form A and form B in the Immediate Memory index in the New Zealand population. Our population was drawn from one geographic location and participants were all over the age of 40, meaning the results may not be generalisable more broadly in New Zealand or overseas.

Conclusion

In a New Zealand cohort, we found a differences in the RBANS immediate memory index between forms A and B. This may be due to one or more phrases that are uncommon in a New Zealand context. We suggests that when using these forms in different English language regions, it is prudent to check for any phrasing that is geographically different , and be prepared to account for this.

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