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Cognitive decline on the Repeatable Battery for the Assessment of Neuropsychological Status in Progressive Supranuclear Palsy

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Abstract

Objective: Progressive supranuclear palsy (PSP) is associated with a variety of cognitive deficits, but few studies have reported on its cognitive trajectory across time, especially on the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS).

Methods: Two hundred twenty participants diagnosed with Richardson's syndrome of PSP (PSP-RS) were evaluated with the RBANS at baseline, six months, and one year with alternate forms.

Results: When using dependent t-tests, significant declines were observed on all Indexes of the RBANS from baseline to six months (ps<0.01). Between six months and one year, significant declines were observed on three Indexes of the RBANS (ps<0.05). Using existing regression-based change formulae from cognitively intact older adults, these participants with PSP showed significant decline on all RBANS Indexes (ps<0.01) across one year. Finally, new regression-based change formulae were developed on this sample of individuals with PSP-RS to more precisely evaluate cognitive change in this condition.

Conclusion: In this large, longitudinal cohort of participants with PSP-RS, many (but not all) showed notable cognitive decline across six months and one year on the RBANS. The different methods of examining change across time yielded different results, with regression-based methods appearing to more accurately capture decline in this sample. These findings are expected to allow clinicians to more accurately evaluate cognitive trajectories in patients with PSP, as well as make better estimates of prognosis and offer more appropriate treatment recommendations. Such findings are also expected to inform clinical trials as to the changes in cognitive outcomes with this neurological condition.

Keywords

progressive supranuclear palsy; RBABS; cognitive change

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Introduction

Progressive supranuclear palsy (PSP) is a rare neurodegenerative condition, which affects multiple brain regions, cortically and subcortically (Boxer et al., 2017). Clinically, the classic phenotype, PSP-Richardson's Syndrome (Hoglinger et al., 2017) presents with a variety of motor disturbances (e.g., early and severe gait instability, vertical gaze palsy, rigidity of the axial muscles, dysphagia, pseudobulbar affect, bradykinesia) (Litvan & Hutton, 1998), neuropsychiatric symptoms (e.g., apathy, depression, sleep disturbances, agitation, disinhibition) (Gerstenecker, Duff, Mast, Litvan, & Group, 2013), and cognitive impairment (e.g., verbal and figural fluency, naming, attention, processing speed, and executive functioning, learning and memory) (Bak, Crawford, Hearn, Mathuranath, & Hodges, 2005; Cotelli et al., 2006; Duff, in press; Gerstenecker, Mast, et al., 2013; Grafman et al., 1990; Litvan, 1994; Paviour et al., 2005; Soliveri et al., 2000). These clinical symptoms culminate in significant functional deficits (Duff, Gerstenecker, & Litvan, 2013). In addition to PSP-RS, the Movement Disorder Society criteria (Hoglinger et al., 2017) describe a number of other variants of PSP, including PSP-ocular motor dysfunction (e.g., vertical gaze palsy, slow vertical saccades), PSP-postural instability (e.g., repeated unprovoked falls, fall or three steps back on the pull-test), PSP-parkinsonism (e.g., asymmetric onset of tremor, bradykinesia, and rigidity, slower progression than PSP-RS), PSP with progressive gait freezing (e.g., isolated gait disorder before other symptoms of PSP), PSP-corticobasal syndrome (e.g., progressive limb rigidity, apraxia, cortical sensory loss, and alien limb), PSP-speech/language disorder (e.g., nonfluent progressive aphasia involving either agrammatism in language production or apraxia of speech), and PSP with frontal presentation (e.g., progressive deterioration of personality, social norms, behavior, and cognition). For additional information about these variants, refer to Boxer et al. (2017).

Although a wide range of cognitive difficulties are seen in PSP-RS, few studies have examined cognitive decline across time in these patients. For example, Litvan and Kong (2014) reported 1 – 2-point declines on Mini Mental State Examination in a small cohort of patients with PSP who were evaluated across three years. In other small samples, yearly changes on Addenbrooke's Cognitive Examination – Revised have been mixed, with some reporting relatively mild declines (<1 point per year) (Ghosh, Carpenter, & Rowe, 2013) and others reporting more sizeable decrements across time (20-point drop over 16 months) (Cushing et al., 2013). Using a more comprehensive evaluation of cognition, the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS), and a much larger cohort of patients with PSP-RS, Boxer et al. (2014) reported a mean 5 – 6-point decline on the RBANS Total Scale score across one year, in both drug-treated and placebo groups in an international clinical trial. Bang et al. (2016) reported on the RBANS Total Scale score in this same clinical trial cohort, and noted that there was considerable variability in the amount of decline across one year. Since they used the same sample as Boxer et al., they also found a mean decline of 6 points on the RBANS Total Scale score, but they additionally reported that some patients declined by as much as 36 scaled score points and others improved by as much as 13 scaled score points. These studies show that a mild amount of decline is expected across one year in patients with PSP-RS, but that there is a wide range of change when considering individual patients. Importantly, it should be noted that the Boxer

et al. and Bang et al. studies, which used the same cohort of patients, only reported on the Total Scale score of the RBANS, and not the other Indexes.

Therefore, the purpose of the present study was to further examine cognitive decline on the RBANS in a large, well-characterized sample of patients with PSP-RS by examining the individual Indexes of the RBANS across six months and one year. It was expected that these patients would show worsening on most Indexes of the RBANS across these two time points. The current study also used to different metrics for examining cognitive change in this cohort: dependent t-tests and regression-based change formulae, the latter of which has not been used to examine change in PSP. As clinical trials in PSP expand, a better sense of the trajectory of cognitive functioning in this cohort could be useful in measuring the effectiveness of future treatments.

Methods

Participants and Procedures

Participants were recruited from 48 study centers in Australia, Canada, France, Germany, the United Kingdom, and the United States for a randomized clinical trial of davunetide vs. placebo (Boxer et al., 2014). Two hundred twenty participants with PSP-RS were included in the final sample. Ethics board approval was obtained at each site and all participants gave written informed consent as per local regulations. All participants met the following inclusion criteria for PSP-RS: at least a 12-month history of postural instability or falls, decreased downward saccade velocity or supranuclear ophthalmoplegia, and an akinetic-rigid syndrome with prominent axial rigidity. In addition, at screening, individuals had to be between 41 to 85 years old, have a Mini-Mental State Examination score ≥ 15, live outside a skilled nursing facility or dementia care facility, be able to ambulate independently or to take at least 5 steps with minimal assistance, have a Progressive Supranuclear Palsy Rating Scale (Golbe & Ohman-Strickland, 2007) score ≥ 40, and be able to undergo an MRI scan during screening. Participants were allowed to take Parkinson's medications if the dose had been stable for 60 days prior to screening. Participants were allowed to take rasagiline or co-enzyme Q10 if the dose was stable for at least 90 days prior to screening. Participants were excluded if: they had a clear and robust benefit from levodopa at the time of screening, evidence of motor neuron disease, or use of acetylcholinesterase inhibitors, antipsychotics (other than quetiapine), memantine, lithium, methylene blue, or other putative disease modifying drugs for PSP. Since Boxer et al. (2014) found no treatment effects of davunetide, the control and treatment arms were merged for these analyses.

Measures

The RBANS (Randolph, 1998) is a brief, individually administered test measuring attention, language, visuospatial/constructional abilities, and immediate and delayed memory. It consists of twelve subtests, which yield five Index scores and a Total Scale score. Normative information from the manual, which is used to calculate the Index and Total scores, is based on 540 healthy adults who ranged in age from 20–89 years old. The Index and Total scores are age-corrected standard scores (M = 100, SD = 15). All subtests were administered and scored as defined in the manual.

Validated translations of the RBANS were used in this study (e.g., following specific linguistic guidelines by a formal translation company, including clinical review and certificates of validation), and all subjects were tested in their primary language. There is a growing literature on the cross-cultural utility of the RBANS, including in Japan (Yamashima et al., 2002), China (Collinson, Fang, Lim, Feng, & Ng, 2014), Australia (Baune et al., 2010), Germany (Goldbecker et al., 2013), Hungary (Juhasz, Kemeny, Linka, Santha, & Bartko, 2003), and United Kingdom, Spain, France, Italy, Canada, and Argentina (De la Torre et al., 2014; Liogier d'Ardhuy et al., 2015); however, the equivalence of normative sets across cultures has not been investigated. We did not observe any systematic variation in performance by country/language, which is consistent with other multinational clinical trials employing the RBANS as either a screening instrument or endpoint.

Data Analyses

First, to examine cognitive change on the RBANS in those with PSP-RS, dependent t-tests were used to compare each Index score of the participants with PSP-RS between: 1) baseline and six months, and 2) six months and one year. Cohen's d, a measure of effect size, was calculated for each comparison (i.e., time 1 – time 2/pooled standard deviation). Second, existing regression-based change formulae from cognitively intact older adults (Duff et al., 2004) were applied to the RBANS Indexes of the current sample of individuals with PSP-RS to see how their change across one year compared to normative data. These change formulae used multiple regression to predict one year scores on the five Indexes and Total Score of the RBANS using baseline RBANS scores and demographic variables in a sample of 223 community dwelling older adults seen in a primary care clinic. A resulting z-score from these change formulae of 0 would indicate no change relative to these cognitively intact older adults, a resulting z-score of −1.645 or lower would indicate a decline, and a resulting z-score of +1.645 or higher would indicate an improvement. One-sample t-tests were used to compare the resulting change scores to a theoretical z-score of 0, which would indicate no change. Finally, using linear regression, one-year scores on the RBANS were predicted from baseline scores in an attempt to provide estimates of normal change across one year in this cohort. As an initial validation of these new regression-based change scores, one-sample t-tests were also used to compare the resulting change scores to a theoretical z-score of 0. An alpha of 0.05 was used throughout.

Results

Two hundred twenty participants with PSP-RS were included in the final sample. They were nearly evenly distributed for gender (52% male and 48% female), with a mean age of 67.5 (SD = 6.5) years. The vast majority was white (88%) and not Hispanic (91%). Disease duration was reported to be less than five years for 92% of the sample, and more than five years for 8%. Based on their baseline Progressive Supranuclear Palsy Rating Scale score, they tended to be mildly to moderately impaired (M = 38.4, SD = 10.9). Daily functioning tended to show increasing dependence (Schwab and England Activities of Daily Living scale: M = 55, SD = 21). Overall, they were mildly depressed (Geriatric Depression Scale: M = 12.5, SD = 6.8) at baseline. See Table 1 for RBANS Index scores at baseline, six

months, and one year, which ranged from severely impaired to low average. Figure 1 also graphically depicts the change in scores from baseline to six months to one year.

Assessing change with dependent t-tests

Using dependent t-tests, significant declines were observed on all Indexes of the RBANS from baseline to six months: Immediate Memory Index ($t[219] = 7.42$, $p<0.01$, $d = 0.36$), Visuospatial/Constructional Index ($t[217] = 2.65$, $p<0.01$, $d = 0.15$), Language Index ($t[219] = 15.62$, $p<0.01$, $d = 1.03$), Attention Index ($t[210] = 5.37$, $p<0.01$, $d = 0.28$), Delayed Memory Index ($t[210] = 4.22$, $p<0.01$, $d = 0.23$), and Total Scale ($t[204] = 12.45$, $p<0.01$, $d = 0.51$). These declines were quite variable, with mean drops of 2 – 12 standard score points and absolute effect sizes ranging from 0.15 – 1.03.

When considering changes from six months to one year, participants showed additional decline on the Visuospatial/Constructional Index ($t[217] = 3.84$, $p<0.01$, $d = 0.21$) and the Attention Index ($t[210] = 3.04$, $p<0.01$, $d = 0.12$), improvement on the Language Index ($t[219] = -2.63$, $p<0.01$, $d = -0.18$), and stability on the Immediate Memory Index ($t[219] = -1.85$, $p = 0.07$, $d = -0.09$), Delayed Memory Index ($t[210] = -0.96$, $p = 0.34$, $d = -0.05$), and Total Scale ($t[204] = -1.13$, $p = 0.26$, $d = -0.04$). These changes were quite mild, with mean changes of −2 – 2 standard score points and absolute effect sizes ranging from 0.04 – 0.21.

Assessing change with existing regression-based change scores

Using existing regression-based change formulae from cognitively intact older adults (Duff et al., 2004), the current sample of individuals with PSP-RS showed significantly more severe change across one year, as depicted by the negative z-scores on all Indexes of the RBANS (e.g., −0.74 – −1.65, see Table 2). Since a z-score of 0 would indicate that the current sample showed the same amount of change as the cognitively intact older adults in Duff et al., the z-scores from the PSP-RS sample was compared to a value of 0 with a series of one-sample t-tests. All of these t-tests were statistically significant: Immediate Memory Index ($t[219] = -7.70$, $p<0.01$, $d = 0.60$), Visuospatial/Constructional Index ($t[216] = -24.86$, $p<0.01$, $d = 1.49$), Language Index ($t[218] = -16.49$, $p<0.01$, $d = 1.28$), Attention Index ($t[214] = -19.95$, $p<0.01$, $d = 1.46$), Delayed Memory Index ($t[213] = -9.04$, $p<0.01$, $d = 0.68$), and Total Scale ($t[209] = -20.50$, $p<0.01$, $d = 1.51$).

Assessing change with new regression-based change scores

Using linear regression, one-year scores on the RBANS were predicted from baseline scores, which provide estimates of normal change across one year in this cohort. For example, the regression model in predicting the Total Scale score at one year, which included the Total Scale score at baseline, accounted for a significant amount of variance, $R^2 = 0.62$, $F(1,212) = 344.47$, $p<0.001$. For each Index score, the final model's R^2, standard error of the estimate, constant, and unstandardized beta weights for the baseline scores are listed in Table 3.

Discussion

Given the near absence of longitudinal analyses of cognition in PSP, the current study sought to examine cognitive decline on the RBANS in a large, well-characterized sample of patients with PSP-RS who were evaluated at baseline, six months, and one year with traditional dependent t-tests and two sets of regression-based change formulae. Such findings may allow clinicians to more accurately track cognitive changes in these patients and provide better estimates of prognosis and recommendations about the need for clinical services. Additionally, as clinical trials in PSP expand, it will be necessary to understand the cognitive trajectory of these patients to better examine the effectiveness of treatments. Consistent with prior studies (Bang et al., 2016; Boxer et al., 2014; Cushing et al., 2013; Litvan & Kong, 2014), significant cognitive declines were observed in this cohort of patients with PSP-RS. For example, as seen in Figure 1, from baseline to six months, declines were observed on all five Indexes of the RBANS and the Total Scale score using dependent t-tests. According to the effect sizes, the largest decline occurred on the Language Index (d = 1.03), with small to medium declines being seen on the Total Scale score (d = 0.51), the Immediate Memory Index (d = 0.36), and the Attention Index (d = 0.28). These declines are quite unexpected given the expected psychometric changes due to practice effects, regression to the mean, and the relatively short retest interval (Bartels, Wegrzyn, Wiedl, Ackermann, & Ehrenreich, 2010; Beglinger et al., 2005; Benedict & Zgaljardic, 1998; Duff et al., 2005). Fewer changes were observed from six months to one year, with additional declines on the Visuospatial/Constructional Index (d = 0.21) and the Attention Index (d = 0.12) and a slight improvement on the Language Index (d = −0.18). The large decline and then subsequent slight improvement on language tests is difficult to explain, although language difficulties have been reported in patients with PSP (Gerstenecker, Mast, et al., 2013). It is possible that this change (i.e., large decline and then slight improvement) is more a function of the psychometric properties of RBANS Language Index than disease characteristics of PSP. Unfortunately, we did not have access to the results of the individual subtests that make up the Language Index, as it would be informative to see the changes on the Picture Naming and Semantic Fluency subtests.

Although dependent t-tests are a more traditional method for examining cognitive decline in a cohort, it can also be instructive to compare the amount of change seen in a cohort to some “normative” change sample. Duff et al. (2004) provided regression-based change formulae for the RBANS from a large cohort of cognitively healthy older adults seen twice across one year. For the Total Scale on the RBANS, the mean decline for the PSP-RS sample was −1.65 compared to healthy older adults, which falls just below the typical cutoff for cognitive decline (<−1.645). This suggests that approximately half of these patients with PSP-RS demonstrated a clinically-meaningful decline on the global measure of cognition on the RBANS. Relatively smaller declines were observed on the Attention Index (−1.58), the Language Index (−1.56), and the Visuospatial/Constructional Index (−1.36). Unlike many other conditions leading to degenerative dementias, the two memory indices of the RBANS (Immediate Memory Index [−0.74] and Delayed Memory Index [−0.78]) showed the smallest amount of decline across one year compared to the healthy cohort. It should be noted that there are some differences between the current PSP-RS sample and the Duff et al.

cohort that could have altered change patterns (e.g., current sample was tested three times across one year vs. Duff et al. was tested twice across one year, current sample were administered alternate forms at each visit vs. Duff et al. were administered the same forms at each visit, current sample was somewhat younger than the Duff et al. sample [67.5 years vs. 72.8 years, respectively]). Despite these differences between the two samples, the current paper demonstrates an application of these regression-based change formulae, which adds to their clinical utility, and allows us to better understand the amount of change seen in the patients with PSP-RS. It seems that regression-based change formulae identified more change in this sample of patients than the traditional method did, which might be expected since the regression-based method accounts for "normal" change on this cognitive battery and demographic variables, whereas the traditional method does not. Although this study was not designed to compare these two different metrics of measuring change, this application in the present sample highlights the differences that can occur with these two different methods. Overall, the absence of improvement due to practice or regression to the mean seen across all Indexes of the RBANS in this cohort seems to reflect an indication of additional cognitive decline in these patients, which is not fully appreciated with the traditional method of assessing change.

In addition to comparing cognitive decline to a normative sample, future clinical trials in PSP may want to know if their participants show similar or different rates of cognitive decline than those in the current sample. As such, regression-based change formulae were developed on the current group of patients. Although we attempted to generate "complex" regression-based change formulae (i.e., those that included both baseline cognitive scores and demographic variables), we ended up with "simple" regression-based change formulae (i.e., those that included only baseline cognitive scores), as the demographic variables did not significantly add to the prediction of follow-up scores in these patients with PSP-RS. In these PSP-RS-specific "simple" change formulae, the equation for predicting follow-up Total Scale scores had the highest percent variance accounted for (approximately 62%) and smallest standard error of the estimate (8.91), which suggests that it might be the most sensitive change score on the RBANS in these types of patients. Such predicted change z-scores would allow one to identify which individuals showed greater decline or improvement than their peers. These regression-based change scores may be fruitful for enriching future clinical trials. For example, if one were examining a potential cognitive enhancer for PSP (e.g., medication, cognitive rehabilitation program), then one might use these regression-based change scores to identify those subjects who were showing more notable decline across time. Testing an intervention in these individuals might allow the research team to reduce the sample size since their cognitive trajectory is more reliably known. Additionally, these results would appear to provide unique insights that might be valuable in the clinical care of these patients. Knowing the current (and perhaps future) cognitive trajectory of an individual with PSP may allow for a more timely orchestration of additional clinical services (e.g., psychological and neuropsychological intervention, occupational therapy, physical therapy, etc.). Future research might examine which cognitive domains decline and in what order for the different subtypes of PSP, as well as how certain patterns of cognitive decline might aid in the differential diagnosis of PSP from other neurological disorders with parkinsonism.

In may be informative to show how these two sets of regression-based change formulae could be used to inform one about the amount of cognitive change seen in an individual. A 67 year old patient with PSP-RS who has 13 years of education is administered the RBANS and gets a Total Scale score of 76. After a year, the patient is re-administered the RBANS and gets a Total Scale score of 70. Although this decline of 6 standard score points clearly reflects some decrement, it is not clear how significant this decrement is relative to some comparative group. Using the regression formulae from Table 2 of Duff et al. (2004), this patient has a predicted follow-up Total Scale score of 83.65 (i.e., predicted Time 2 score = 37.65 + [76*0.75] – [67*0.23] + [3*1.47] = 83.65) compared to a large cohort of healthy older adults tested twice across one year with the RBANS. When the observed follow-up score is compared to this predicted follow-up score, the resulting z-score is −1.75 (i.e., [70 – 83.65] / 7.81 = −1.75), which falls below the traditional cutoff of −1.645 indicating a reliable decline in overall cognition compared to the sample of Duff et al. So, compared to healthy older adults, this patient showed more decline than 97% of them. Please note that the interested reader should refer to Duff et al. for the proper coding of demographic variables, regression-based prediction equations, and standard error of estimates needed to calculate this z-score. Alternatively, if one wanted to see how much this patient's cognition change compared to other patients with PSP-RS, then he/she could apply the newly developed regression-based change equations from the current study. Using the prediction equation in Table 3, this patient has a predicted follow-up Total Scale score of 70.24 (i.e., predicted Time 2 score = 1.08 + [76*0.91] = 70.24) compared to other patients with PSP-RS tested across a similar interval. When the observed follow-up score is compared to this predicted follow-up score, the resulting z-score is −0.03 (i.e., [70 – 70.24] / 8.91 = −0.03), which falls between the traditional cutoffs of ±1.645 indicating no change compared to this sample. So, compared to other patients with PSP-RS, this patient showed a very similar level of cognitive change. By using these two sets of regression-based change scores, clinicians and researchers can more accurately identify the magnitude of cognitive change in an individual patient or research participant.

Despite the current findings showing the amount of longitudinal change on the RBANS in patients with PSP-RS, some limitations should be mentioned. First, subtest scores for the RBANS were not available for analysis. It is possible that individual subtests show different patterns of cognitive change than the more omnibus Indexes in these individuals with PSP-RS. Second, the current study used a cohort of patient who were relatively early in the course of their disease (e.g., 91% had a disease duration of <5 years). In this way, our results likely apply to an early "window" of PSP-RS, rather than the entire spectrum. Third, excluded from these analyses were 41 participants who did not complete their one-year follow-up visit. It is possible that these early drop-out participants from the davunetide clinical trial would have provided a different picture of cognitive change in PSP-RS if they had been included. However, when we compared the amount of change on the RBANS Total Scale score across 6 months for those who did or did not complete the one-year visit, there were no differences, with both groups declining by approximately 6 standard score points ($t[244] = 0.31$, $p = 0.76$). Fourth, there are inherent limitations when using cognitive measures in multi-cultural studies (e.g., equivalency of the various non-English RBANS translations, validity of applying North American normative data to non-North American

subjects, applying regression-based change formulae developed in solely English-speaking samples to non-English-speaking samples). However, some of these limitations are minimized in our within-subject design, where each individual was compared to him/herself across the three assessments. Regardless of these limitations, the current study provides additional information about the amount of longitudinal decline on the RBANS that might typically be expected in patients with PSP-RS.

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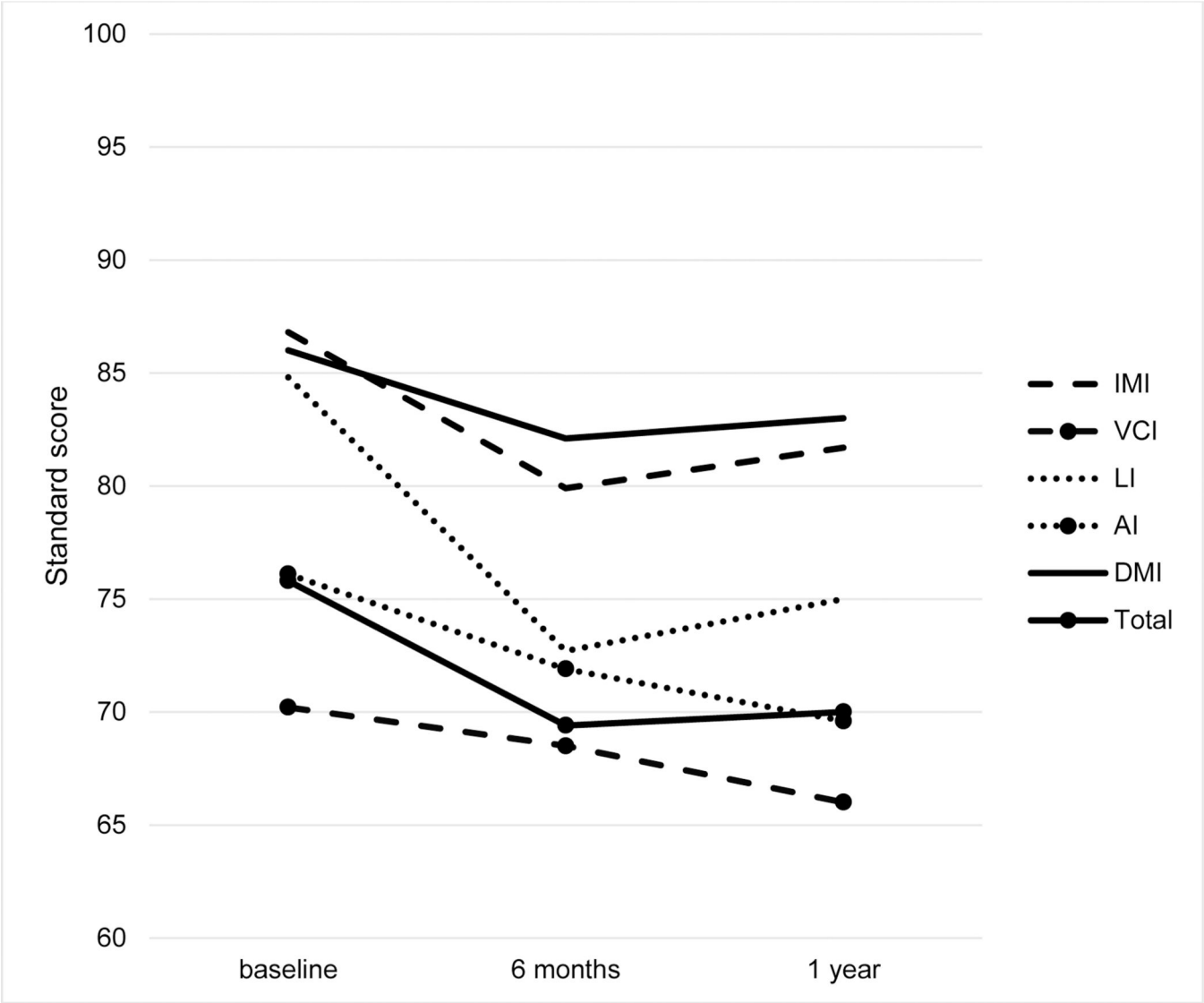

Figure 1.

RBANS Indexes at baseline, six months, and one year

Note. IMI = Immediate Memory Index, VCI = Visuospatial/Constructional Index, LI = Language Index, AI = Attention Index, DMI = Delayed Memory Index, Total = Total Scale. Please note that some of the lines have closed circles to separate them from lines without circles.

Table 1

RBANS Indexes at baseline, six months, and one year

RBANS score	Baseline	Six months	$r_{0–6}$	$d_{0–6}$	One year	$r_{6–12}$	$d_{6–12}$
Immediate Memory (n = 220)	86.8 (18.6)	79.9 (19.6) *	0.74	+0.36	81.7 (21.6)	0.76	−0.09
Visuospatial/Constructional (n = 218)	70.2 (12.2)	68.5 (11.1) *	0.64	+0.15	66.0 (12.7) *	0.69	+0.21
Language (n = 220)	84.8 (10.5)	72.7 (13.0) *	0.54	+1.03	75.0 (13.2) *	0.49	−0.18
Attention (n = 211)	76.1 (14.8)	71.9 (15.6) *	0.72	+0.28	69.6 (16.0) *	0.77	+0.12
Delayed Memory (n = 211)	86.0 (16.3)	82.1 (17.6) *	0.68	+0.23	83.0 (19.3)	0.73	−0.05
Total Scale (n = 205)	75.8 (12.5)	69.4 (12.8) *	0.83	+0.51	70.0 (14.2)	0.86	−0.04

Note. Means and standard deviations (in parentheses) are presented.

*different from preceding visit at $p < 0.01$, $r_{0–6}$ = correlation between baseline and six months, $r_{6–12}$ = correlation between six months and one year, $d_{0–6}$ = Cohen's d between baseline and six months, $r_{6–12}$ = Cohen's d between six months and one year. Positive Cohen's d values reflect a decline from time 1 to time 2, where negative Cohen's d values reflect an improvement from time 1 to time 2.

Table 2

RBANS Indexes z-scores based on Duff et al. (2004)

RBANS score	z-scores* Duff et al. (2004)	range of z-scores
Immediate Memory	−0.74 (1.43)	−5.28 – 2.90
Visuospatial/Constructional	−1.36 (0.80)	−4.54 – 1.24
Language	−1.56 (1.40)	−5.91 – 2.03
Attention	−1.58 (1.16)	−5.43 – 1.41
Delayed Memory	−0.78 (1.26)	−4.55 – 2.59
Total Scale	−1.65 (1.17)	−5.55 – 1.24

Note. Means and standard deviations (in parentheses) are presented in the top row of each cell, and the range of scores is presented in the bottom row of each cell.

* = all of these z-scores are statistically significantly different from 0 at $p<0.001$.

Table 3

Regression equations for predicting one year RBANS Indexes in the PSP sample

RBANS score	R^2	SE_{est} [a]	C [b]	B [c]	Predicted One Year Score
Immediate Memory	0.48	15.58	11.70	0.81	(11.70 + [baseline index * 0.81])
Visuospatial/Constructional	0.38	10.02	20.84	0.64	(20.84 + [baseline index * 0.64])
Language	0.15	12.23	34.14	0.48	(34.14 + [baseline index * 0.48])
Attention	0.52	11.17	9.58	0.79	(9.58 + [baseline index * 0.79])
Delayed Memory	0.46	14.39	13.38	0.81	(13.38 + [baseline index * 0.81])
Total Scale	0.62	8.92	1.08	0.91	(1.08 + [baseline index * 0.91])

Note. Index scores are age-corrected standardized scores.

[a] Standard error of the estimate,

[b] Constant,

[c] Unstandardized beta weight for the baseline Index score.

To utilize these equations, (Observed One Year Score – Predicted One Year Score) / SE_{est}, which will yield a z-score indicating how much change has occurred in an individual compared to this sample.