LONG-TERM RECOVERY OF NAMING ABILITIES FOR INDIVIDUALS WITH APHASIA

By

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Abstract

Aphasia is an acquired language impairment that can affect multiple aspects of an individual's communication. Although aphasia can vary with each individual, a universal characteristic is anomia, an impairment of naming abilities. Many studies have examined improvement of language skills over time in this population, but few specifically look at naming recovery over time. This study examined long-term recovery of naming abilities using the *Boston Naming Test* (*BNT*) scores from participants in the University of Arizona Aphasia Research Project. Each participant's overall change in *BNT* scores and the slope of their recovery were calculated to determine extent and rate of longitudinal naming improvement. In addition, independent variables including age, education, time post-onset (TPO) in months, and initial *BNT* score were evaluated for their predictive value relative to naming improvement. The effects of behavioral treatment—group, individual, and both—were also examined relative to *BNT* change. There was significant improvement on both the *BNT* change score and slope across all levels of severity and treatment groups. In addition, none of the independent variables were significant predictors of improvement. These results indicated that significant improvement of naming abilities is possible years after a stroke, regardless of demographics and initial severity.

Introduction

Aphasia is an acquired language impairment that affects comprehension and production of spoken and written language. The nature and severity of the language impairment varies depending on the location and extent of the damage to cerebral tissue. However, a universal characteristic among individuals with aphasia is anomia, an impairment of naming and word retrieval. While anomia presents a problem for patients at the onset of their aphasia, there is empirical evidence of improvement over time (Basso, Capitani, & Vignolo, 1979; Deloche et al., 1997; Hinckley & Craig, 1998; Freed, Celery, & Marshall, 2004). It is not clear, however, how much improvement might be expected in an individual in the months and years that follow the onset of the anomia. To date, there has been little research to examine long-term improvement of naming or the factors that are associated with improvement. This paper will examine naming performance of a relatively large cohort over long recovery periods.

While anomia is a universal characteristic among individuals with aphasia, the nature of the underlying deficit can vary (Benson, 2007). Since different components of the naming process are supported by different parts of the language network of the brain, the site of lesion or defect can affect specific aspects of the process. Benson (2007) described anomia subtypes due to underlying impairments of word production, word selection, semantics, and connection (i.e., disconnection). Each subtype was associated with specific aphasia syndromes and the typical anatomical lesion location. Similarly, Goodglass, Kaplan, Weintraub, and Ackerman (1976) found differences in anomia characteristics among aphasia types: Broca's, Wernicke's, anomic, and conduction. However, they found similar levels of naming difficulty across aphasia subtypes, despite differences in the

underlying impairment. Overall, these studies indicate that anomia is a complex characteristic that can vary in nature and severity, despite being a universal deficit.

Some studies have been conducted to examine the predictive value of independent variables relative to improvement in naming abilities and overall language skills. Howard, Patterson, Franklin, Orchard-Lisle, and Morton (1985) looked at the predictive value of certain variables in the context of naming improvement alone. They performed subsequent analyses with their group to see what variables were predictive of naming improvement. They found aphasia type, the patient's age, and the duration of aphasia had no significant relationship to the extent of naming improvement. A recent study by Goodman and Shatto (2013) that focused on overall language improvement over time for individuals with aphasia, using aphasia quotient (AQ) scores from the *Western Aphasia Battery* (*WAB*), had different findings. They found that individuals with aphasia continued to show improvement in language skills long after their initial stroke. In addition, they found several variables that were significant predictors of overall language improvement over time. With respect to change in AQ from initial to final scores, age at time of stroke was a significant predictor of positive change over time. With respect to slope of the AQ scores over time, age at time of stroke and education were predictive of change in AQ, in that younger individuals with a higher level of education had greater improvement. Naming performance was part of the language profile in this study, but to examine naming specifically, a test such as the *Boston Naming Test* (*BNT*) would be useful.

The *BNT* is a subtest of the *Boston Diagnostic Aphasia Examination* (*BDAE*), a battery of tests designed to characterize aphasia type and severity (Kaplan, Goodglass, & Weintraub, 1983; Goodglass, Kaplan, & Barresi, 2000). The *BNT* is a confrontation picture

naming test that offers a more specific measure of verbal naming ability than most subtests of standardized aphasia batteries. The 60-item version of this test is often used for research purposes. Each picture consists of a black and white line drawing, and the items increase in difficulty throughout the test based on typical frequency of exposure or use. The original version of the *BNT* (Kaplan et al., 1983) prompts spontaneous responses and offers phonemic and semantic cues, as needed. The second version of the test introduced multiple choice and accepts these responses if a client cannot name an item with any of the given cues (Kaplan et al., 1983). Widespread clinical and empirical use of the *BNT* has provided support for its sensitivity in measuring naming improvement in individuals with aphasia.

The *Western Aphasia Battery* (*WAB*), another popular aphasia diagnostic battery, also has a naming subtest (Kertesz, 1982). This subtest provides a sample of naming ability for relatively common objects as well as some additional lexical retrieval tasks, while the *BNT* specifically evaluates verbal confrontation naming. Since the *BNT* is more specific, its usefulness for studies that focus exclusively on naming is understandable. For many naming treatment studies, the *BNT* is used to evaluate a participant's initial severity of anomia (Freed et al., 2004; Fillingham, Sage, & Ralph, 2005; Fillingham, Sage, & Ralph, 2006; Sage, Snell, & Ralph, 2011). The *BNT* has also been used to collect pre- and post-therapy scores for participants in an effort to determine the effectiveness of different treatments (Nettleton & Lesser, 1991; Hinckley & Craig, 1998).

Nettleton and Lesser (1991) and Hinckley and Craig (1998) examined change in performance on the *BNT* over time in individuals with aphasia. Nettleton and Lesser (1991) had 6 participants with chronic aphasia divided into three groups based on the nature of their naming disorders: semantic disorder, phonological lexicon disorder, and

phonological assembly buffer disorder. The participants with semantic and phonological lexicon disorders received model appropriate therapy, while those with phonological assembly buffer disorder received model inappropriate therapy. The participants who received semantic therapy for their semantic naming disorder improved 17 points and 8 points on the *BNT* over the course of 27 weeks. The participants who received phonological therapy for their phonological lexicon disorder improved 1 and 3 points over a 27 week therapy. The average improvement in those receiving model appropriate therapy was +7.25. The last set of participants who received treatment that was not consistent with the underlying deficit (i.e., model inappropriate therapy) declined by -6 points over the same length of time.

Hinckley and Craig (1998) also used *BNT* scores to measure naming improvement over time. Their therapy structure consisted of a 6-week intensive treatment period, followed by no treatment for 6-8 weeks, and then a second intensive treatment period of 6 weeks. *BNT* pre-test scores for the first intervention period averaged 21 out of 60 with a range of 0 to 53. *BNT* post-test scores for this period averaged 29 out of 60 with a range of 3 to 58. This represents an average improvement of 8 points. They revealed that 87% of their participants improved their raw *BNT* scores, which was a statistically significant change. During the no treatment period, 40% of participants improved, 33% maintained scores, and 27% decreased. All participants remained above baseline during this period. In the second intervention period, there was an average gain of 3 points on the *BNT*, with 67% of participants demonstrating improvement, 27% of subjects maintaining scores, and 1 subject decreasing. The difference between the pre- and post-test scores for this second treatment period was significant.

In addition to using the *BNT* to examine naming recovery in individuals with a language impairment, this test has also been used to examine language performance in older adults as they age. Ivnik, Malec, Smith, Tangalos, and Petersen (1996) compiled normative data for the *BNT* and several other neuropsychological tests based on the performance of 750 cognitively normal older adults aged 56- to 97-years-old. This project was part of the Mayo Clinic's Older Americans Normative Studies (MOANS). Ivnik et al. generated a scaled score system for the *BNT* to account for raw score variability across age and education levels. The ranges of *BNT* scores corresponding to the scaled score changed slightly with each of the 11 age bands, indicating decline in naming and language performance as adults age.

Sachs et al. (2012) established reliable change indices for the *BNT* with 844 cognitively normal adults, aged 56 and older. These individuals were tested at baseline, then retested at 9-15 month and 16-24 month periods. They found that a 4-point decline or 5-point improvement at the 9-15 month retest period and a 6-point decline or 7-point improvement at the 16-24 month retest period were considered reliable changes. Since the current study looks at naming performance of older adults over time, referencing these accounts of decline due to aging is relevant. In addition, from these two studies, we determined that 5-point or greater improvement on the *BNT* constitutes a conservative benchmark of reliable change for an individual with aphasia.

Other studies have examined naming recovery using other measures. Most of these studies are specific to treatment outcome research, such as semantic versus phonological naming treatments (Howard et al., 1985; Nettleton & Lesser, 1991; Hillis, 1998). Although these studies provide valuable information about existing naming treatments, they are

limited with respect to cohort size and duration of follow-up. A limitation of previous research has been the small size of the cohorts, including case studies (Thompson & Kearns, 1981; Le Dorze & Pitts, 1995; Best, Howard, Bruce, & Gatehouse, 1997; Hillis, 1998) and groups of two to seven participants (Nettleton & Lesser, 1991; Pring, Hamilton, Harwood, & Macbride, 1993; Lowell, Beeson, & Holland, 1995; Miceli, Amitrano, Capasso, & Caramazza, 1996; Pedersen, Vinter, & Olson, 2001; Fillingham et al., 2005). A few longer studies have evaluated naming recovery in a large group of 12 individuals (Howard et al., 1985) or 18 individuals (Deloche et al., 1997), providing a broader picture of improvement for a range of aphasia profiles.

Many published studies focused primarily on the effects of treatment over short periods of time (Thompson & Kearns, 1981; Howard et al., 1985; Pring et al., 1993). To evaluate these short-term effects, Pring et al. evaluated participants at 1 month post-treatment, while Thompson and Kearns measured treatment maintenance over an unspecified several months post. While these short-term effect studies have clinical value, they do not provide information on the long-term maintenance of treatment effects. They also do not evaluate the benefits of continuous treatment over time for naming and other aspects of language impairment over time. A variation of the short-term research has been to evaluate participants receiving a limited number of treatment sessions (Thompson & Kearns, 1981; Deloche et al., 1997). For example, Thompson and Kearns distributed therapy over 84 sessions while Deloche et al. had a total of 25 sessions for each participant. In summary, studies of naming recovery are varied in intensity and length of treatment, and few studies followed participants for more than a year to measure naming improvement or maintenance.

The current study sought to examine the long-term recovery of naming abilities in individuals with aphasia. To accomplish this goal, we conducted a retrospective analysis of data collected by the Aphasia Research Project and the Clinic for Adult Communication at the University of Arizona over the past 25 years. The University of Arizona has a history of seeing individuals with aphasia and developing more effective treatments for various associated impairments, including anomia. Since naming performance is a universal issue for individuals with aphasia, it has been consistently tested by the Aphasia Research Project using the naming subtest on the *WAB* and the *BNT* for many individuals involved in this research project. Data were available to examine variables such as initial *BNT* score, age, and time post-onset (TPO) in months compared to change in *BNT* scores over time.

Based on previous studies of longitudinal aphasia recovery, we hypothesized that naming abilities will improve significantly over time. This work was intended to expand upon work by Goodman and Shatto (2013), who examined *WAB* aphasia quotients over time from the Aphasia Research Project. In this study, we expected age to be a significant predictor of positive change in *BNT* scores over time, based on Goodman and Shatto's findings. In addition to age, three other independent variables will be evaluated for predictive value—education, initial TPO in months, and initial *BNT* score. Among these four variables, we predicted that initial *BNT* score would be a significant predictor of improvement over time, particularly relative to *BNT* slope.

Methods

The data for this study was retrieved from electronic and paper records. After reviewing data from the past 25 years of the Aphasia Research Project, a total of 169 participants had at least one *BNT* administration and were compiled in a database exclusively for *BNT* scores. To effectively examine long-term recovery of naming, only individuals with multiple *BNT* scores from different test administrations were included in this study. There were a total of 72 participants with more than one *BNT* score. Each *BNT* score had to be out of a total of 60 which eliminated data from two individuals because fewer than 60 items were administered. Individuals with other neurological issues, including encephalitis, were excluded. Four individuals were removed from the group due to marked decline in *BNT* scores as a result of illnesses such as dementia. In addition to these criteria, participants with an initial *BNT* score of 52 or above were considered within normal limits. Eight participants fit this description and were not included in the data analysis. After all inclusion criteria was considered, a total of 47 participants were included in the data analysis.

The majority of study participants were male (36 males and 11 females). As indicated in Table 1, the mean age at the time of the first *BNT* administration was 60.74 years. The earliest time post-onset for an individual test administration was 0.33 months, during the acute recovery period, and the latest was 162.44 months post-onset of stroke. The number of *BNT*s administered to each individual ranged from two to six tests. The average time post-onset (TPO) of the initial evaluation was 26.29 months (SD = 35.06). We could not obtain educational information for 9 participants, leaving a total of 38 in this subset of the data. Within this cohort, the average completed education was 14.63 years,

with a minimum of 10 years. Charts were reviewed to determine whether individuals were enrolled in speech-language treatment. Of the 47 individuals, 6 received group therapy only, 18 received individual therapy only, and 23 received both. A complete set of data for all participants can be found in Appendix A.

Table 1: Summary of participant characteristics.

Characteristics	n	Mean	SD	Range
Gender				
Male	36			
Female	11			
Treatment				
Group Only	6			
Individual Only	18			
Both Group & Individual	23			
Age at Initial *BNT* (years)	47	60.74	14.32	18.5-85
TPO at Initial *BNT* (months)	47	26.29	35.06	0.33-162.44
Initial *BNT* Score	47	25.94	18.22	0-51
Education (years)	38	14.63	3.28	10-22

Data Quality Assurance

To validate scores in the electronic database, individual paper records were checked. This was completed by referring to the original *BNT* booklet to check the test date and count the number of spontaneously correct responses. These scores were either compared to the recorded score in the electronic database, or recorded separately if it was not already in the database. If a booklet was not available, clinical reports were used to confirm test dates and scores. Of the 47 participants in the final group, 38 participants had the original booklet or report with which to validate their test dates and scores. After the validation process was concluded, 9 scores out of 137 total scores were changed, with an average change in *BNT* score of 1 point.

Statistical Analysis

Analysis of *BNT* Change Scores

A paired samples t-test was performed to compare initial *BNT* scores and final *BNT* scores for each participant. To provide a measurement of overall change, initial *BNT* scores were subtracted from final *BNT* scores. To further examine performance relative to initial severity, the data were analyzed separately for those with initial scores between 0 and 29 and those between 30 and 51. An independent samples analysis was performed to compare the differences in *BNT* change between the two severity groups. A bivariate correlation analysis was also performed to identify relationships between the dependent variable of *BNT* change and several independent variables, including: age at the time of the initial *BNT* evaluation, education, initial TPO in months and initial *BNT* score.

Analysis of Change in *BNT* Score over Time

In order to estimate the rate of change in *BNT* scores over time, the slope of the line of best fit was calculated for each participant. The line of best fit was also calculated in MatLab for the group as a whole and for the two severity groups. To examine the predictive value of independent variables, a simple linear regression was run using SPSS on the slope lines for each individual. These independent variables included age at the time of initial *BNT* evaluation, education, initial TPO in months, and initial *BNT* score. *BNT* slopes were also analyzed for the mild-moderate group (raw score = 20-52) versus the severe group (raw score <30) using an independent samples t-test.

Because all individuals received some level of treatment, we also wanted to see if there were any significant differences among the three treatment groups—group treatment

only, individual treatment only, or both. A one-way analysis of variance (ANOVA) was performed to compare the means of *BNT* change for each treatment group.

Results

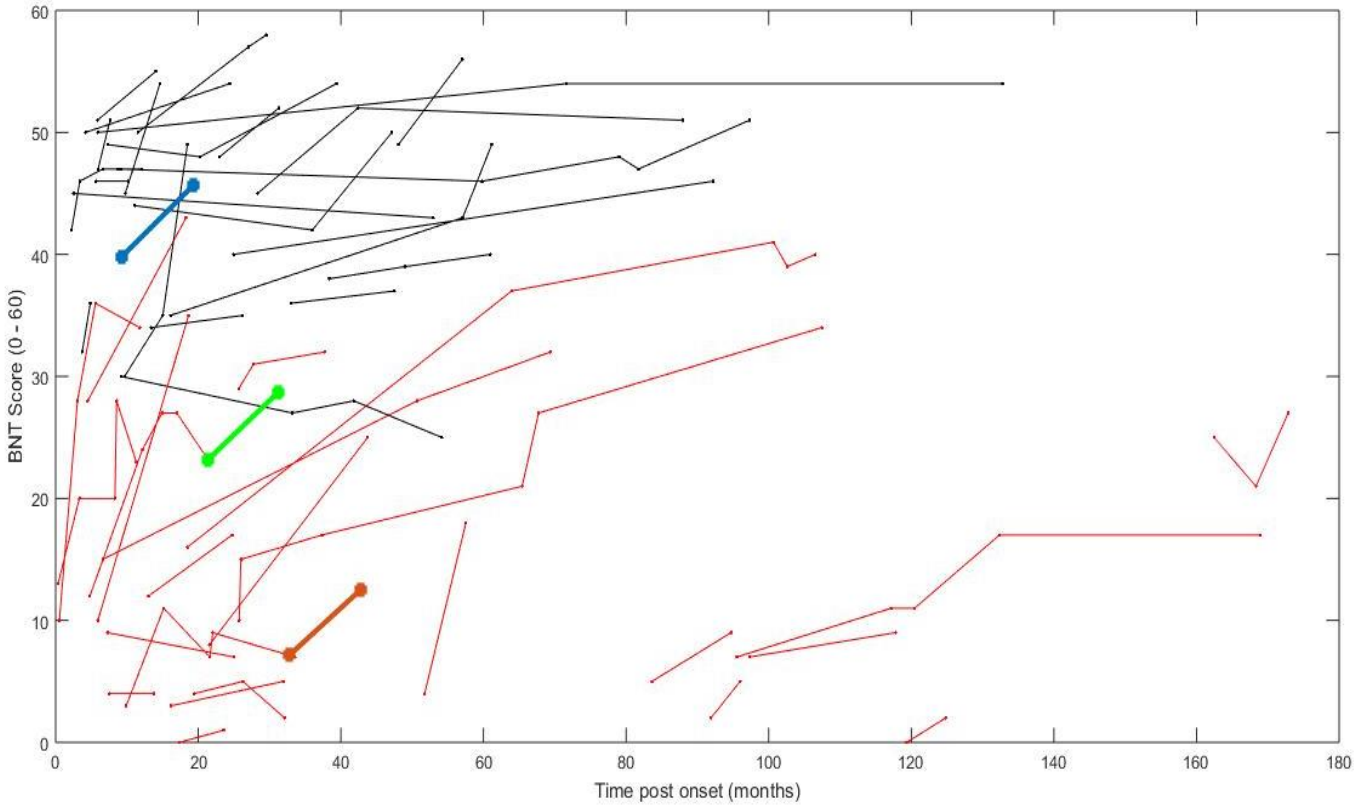
Analysis of *BNT* Change

The mean of all initial *BNT* scores was 25.62 (*SD* = 18.19), which was significantly different than the final mean of 32.70 (*SD* = 18.38), $t(46) = -6.105$, $p < 0.001$. The overall average change in *BNT* score for the entire group was +7.04 over an average of 27.12 months. There were 41 participants who improved an average of +8.34, with a range of 1 to 25 point improvement and an average of 2.95 test administrations. Four participants declined an average of -2.75, with a range of -5 to -2 point decline and an average of 2.75 test administrations. Finally, two participants showed no difference between their initial and final *BNT* scores, with an average of 2 test administrations. For all participants, the average change in *BNT* per year was +7.01 (*SD* = 9.86), calculated by dividing change in *BNT* score by elapsed time between each test administration (in months), and multiplying the quotient by 12.

The *BNT* scores for each participant were plotted against the respective times post-onset in months. Figure 1 is the scatterplot of all scores, with those from a given individual connected. The initial severity scores were distributed throughout the range, with about half of the individuals scoring from 0 to 29 (*n* = 23), and half scoring between 30 and 51 (*n* = 24). The former group was considered severe, whereas the latter reflected mild-moderate impairment. Participants in the severe group improved an average of +8.67, while participants in the mild-moderate group improved an average of +5.43. An independent

samples test was used to compare the mean gain scores of each severity group and revealed that the difference was not significant, $t(45) = -1.41$, $p = 0.166$.

Figure 1: Time post-onset in months versus *BNT* score for 47 participants.



Notes: Red lines indicate severe group, black lines indicate mild group. Blue and orange line represent mean of slope for line of best fit for each respective severity group. Green line represents mean of slope for line of best fit for entire cohort.

Analysis of the Slope of Change in *BNT* Score

The slope of the line of best fit for the entire cohort was 0.56 ($SD = 0.802$), which was significantly different than zero, $t(46) = 4.784$, $p < 0.001$. For the severe group, the average slope of the line of best fit was 0.584 ($SD = 0.934$) and the mild-moderate group was 0.537 ($SD = 0.672$). There was no significant difference between the severity groups with regard to slope, $t(45) = 0.197$, $p = 0.844$.

A linear regression model was implemented to examine the predictive value of several independent variables relative to overall change in *BNT* scores and the slope of change. The independent variables included: age, education, initial TPO in months, and initial *BNT* score. The results of these linear regression models are compiled in Table 2. The model was not significant for *BNT* change, $F(4, 33) = 1.47$, $p = 0.235$, or for *BNT* slope, $F(4, 33) = 0.478$, $p = 0.751$.

Table 2: Linear regression results for *BNT* change and *BNT* slope.

Independent Variable	*BNT* Change		*BNT* Slope	
	t	*p value*	*t*	*p value*
Age	0.240	0.812	0.430	0.670
Education	-1.717	0.095	-0.368	0.715
Initial TPO in months	-1.629	0.113	-0.824	0.416
Initial *BNT* score	-0.924	0.362	0.652	0.519

Notes: For *BNT* change, *R* = 0.389; *R* Square = 0.151; Adjusted *R* Square = 0.048; Std. Error of the Estimate = 7.681.
For *BNT* slope, *R* = 0.234; *R* Square = 0.055; Adjusted *R* Square = -0.060; Std. Error of the Estimate = 0.821.

In addition to the linear regression model, bivariate correlation analyses were performed to examine the strength of relationships between the independent variables and the dependent variables of *BNT* change and slope (see Table 3). There was a significant correlation between initial TPO in months and initial *BNT* score ($r = -0.325$, $n = 47$, $p = 0.026$) and between *BNT* change score and *BNT* slope ($r = 0.404$, $n = 47$, $p = 0.005$).

Table 3: Pearson correlation coefficients (*r*) for bivariate analyses.

	Age	Education	Initial TPO-m	Initial *BNT*	*BNT* Change	*BNT* Slope
Age		0.122	-0.176	-0.043	0.101	0.140
Education			0.504	0.436	0.108	-0.022
Initial TPO-m				-0.325*	-0.197	-0.135
Initial *BNT*					-0.195	-0.009
BNT Change						0.404**
BNT Slope						

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).
Notes: $n = 38$ for Education; $n = 47$ for all other independent variables

The average *BNT* gain was calculated with respect to whether an individual received treatment, and what type. Those who participated in group treatment only showed an average gain of 5.67 points. Participants who only received individual therapy had an average gain of 6.11, and those who received both group and individual therapy had an average gain of 8.22. A one-way analysis of variance (ANOVA) was performed to compare the means of *BNT* change among three treatment groups. As shown in Table 4, there was no significant difference among the three groups, $F(2, 44) = 0.452$, $p = 0.639$.

Table 4: ANOVA results with *BNT* change as dependent variable.

	Sum of Squares	df	Mean Square	F	Significance
Treatment Type	58.365	2	29.318	0.452	0.639
Within Groups	2853.024	44	64.841		
Total	2911.660	46			

Discussion

In this study, we examined change in performance on the *Boston Naming Test* (*BNT*) over time in a cohort of 47 individuals. The entire group improved an average of +7.04 over approximately 27 months. This overall improvement was significant. This included 41 participants who improved 8 points, while only 6 participants declined or did

not change over time. In addition to *BNT* gain, the slopes of the lines of best fit were positive for the group as a whole regardless of severity, demonstrating improvement over time across the cohort. The entire group showed an average improvement of about 7 points on the *BNT* per year. According to Sachs et al. (2012), an improvement of 7 points is a reliable change within a 16-24 month period, indicating that our cohort's improvement was reliable.

When the *BNT* scores were examined by group severity, we found the severe group improved an average of +8.67, and the mild-moderate group's scores improved an average of +5.43. Since there was no significant difference in the average improvement for each severity group, we can conclude that initial level of severity did not have a significant influence on the potential to improve. Clinically, this indicates a patient typically has the ability to improve on the *BNT* regardless of the initial severity of their naming ability. However, in the mild-moderate group, we observed a "ceiling effect" where a few mildly impaired individuals had limited room for improvement. By contrast, a few individuals in the severe group showed modest improvement that was likely limited by impaired speech production.

The linear regression model revealed no significant predictors of naming improvement. This indicated that we cannot predict the trajectory of naming improvement over time based on independent variables such as age, education, initial TPO in months, or initial *BNT* score. This was consistent with Howard et al.'s findings (1985). They also looked at naming improvement over time, and found aphasia type, age, and duration of aphasia had no significant relationship to extent of improvement over time. Our results were not congruent with Goodman and Shatto's (2013) findings, who found age at time of

stroke and education to be significant predictors of overall language improvement. The disagreement between Goodman and Shatto's results and ours is surprising given the overlapping cohort. The difference in these particular results may be attributed to the smaller cohort, 47 compared to 73 participants. Our results can be considered positive in a clinical setting because they indicate that any individual has the potential to improve regardless of their demographics, initial severity, and time post-onset of stroke.

Treatment was another variable explored in the context of this study. Three treatment groups were defined at the beginning of this study—group treatment only, individual treatment only, and both group and individual treatment. These categories are coarse because we did not have precise data for each participant. There was no significant difference between groups, but the average improvement of each treatment group was in the expected order of 5.67 for group only, 6.11 for individual only, and 8.22 for both. Those receiving only group therapy exhibited the lowest average improvement over time, while the individuals who received both types of treatment had the highest average improvement. This was an interesting result and could be explored further with a larger cohort to determine if this is a significant trend.

Despite the *BNT*'s usefulness in providing a measurement of confrontation naming ability, there is still little information in the literature regarding long-term recovery of naming. With this in mind, our use of the *BNT* to examine measures of naming ability over an extended period of time is valuable. Our findings demonstrated the possibility of continued improvement in naming abilities over time through *BNT* gain values and slopes of recovery. We tested *BNT* change and slope relative to no change, but normative data from the MOANS indicate that a decline in performance is to be expected in individuals

over the age of 55. Since our cohort consists of older individuals, we speculate that the improvement we found might be greater if one considers these scores relative the expected potential for decline.

Our cohort was one of the largest used to examine long-term recovery of naming abilities for individuals with aphasia. In addition to a larger cohort, our study also examined recovery over a much longer period of time than existing studies. For example, Thompson and Kearns (1981) evaluated maintenance of treatment effects over several months post-treatment, which was one of the longer studies that looked at naming recovery. Our participants received treatment and *BNT* administrations over a range of 1 month to 10 years, which provides data on recovery over a substantially long period of time. Whereas other studies of this nature typically looked at improvement in the context of one type of treatment, in this study we aimed to determine the potential for improvement regardless of the treatment provided. In particular, we demonstrated that the long-term gains can be expected to average 7 points per year. This was similar to the improvement noted by researchers who examined naming in response to treatment over a shorter period of time (Deloche et al., 1997; Nettleton & Lesser, 1991). Our study did not control for the intensity or duration of treatment, so a direct comparison is not possible, but the convergence of improvement of an average of 7 points per year emerges as a potentially useful expectation.

We also examined the slopes for each individual's improvement to establish their rates of recovery, in addition to the extent of improvement. To our knowledge, no other studies have examined long-term recovery of naming using slope. With this in mind, our results contributed more information about long-term recovery of naming.

A limiting factor of this study was incomplete data regarding the participants' treatment type and length of treatment. The overall size of the cohort also limits the potential predictive power of the study. It would be interesting to see if accounting for these two limitations in a future study has an impact on the significance of results. Another limitation of our study was not all individuals received test administrations over multiple years, instead receiving administrations that were only a few months apart. With this in mind, the change in *BNT* per year was extrapolated based on these individuals' improvement over the course of a few months.

In summary, we achieved a better understanding of what naming improvement looks like over time for different ages and levels of severity using the *BNT*. We also estimated the tangible amount of improvement on the *BNT* per year for individuals with aphasia. Overall, we found naming abilities can improve over time for individuals with aphasia regardless of a variety of factors such as age or time post-onset. The improvement may be dependent upon continued treatment (individual or group) because that was the nature of our group. Additional research is needed to determine the role of treatment in long-term recovery and maintenance of naming improvement.

Appendix A: Individual data for participants.

ID	Age at First Test	Ed Level	Gender	Initial TPO-m	Initial *BNT*	Final *BNT*	Change in *BNT*	*BNT* Slope	Number of *BNT*s	Elapsed time between *BNT*
105	58.4		M	2.24	42	47	5	0.3892	5	9.83
108	18.5	12	M	38.37	38	40	2	0.0885	3	38.37
113	65.8	10	M	119.34	0	2	2	0.3665	2	5.46
114	47.8	16	M	162.44	25	27	2	0.1497	3	10.43
121	74.6	18	M	6.61	15	32	17	0.2752	3	62.76
124	37.5	14	F	8.75	47	51	4	0.0312	5	88.57
127	77.1		M	7.33	49	54	5	0.168	3	32.06
128	69.4	12	F	18.48	16	40	24	0.261	5	88.04
141	53.6	20	M	5.93	50	54	4	0.0319	3	126.87
143	70.4		F	9.17	30	25	-5	-0.0999	4	45
148	**78.6**		**M**	**7.73**	**54**	**54**	**0**	**-0.0061**	**3**	**56.81**
150	59.8	20	M	11.11	44	50	6	0.1252	3	36.04
155	66.9		M	11.54	50	58	8	0.4469	3	18.02
156	62.4	18	M	28.31	45	51	6	0.0705	3	59.67
159	**60.4**		**M**	**56.05**	**56**	**56**	**0**	**0**	**3**	**24.23**
162	48.7	12	F	16.12	35	49	14	0.2639	3	45.04
171	**42.5**		**F**	**33.63**	**57**	**60**	**3**	**0.0912**	**2**	**32.91**
172	**77.2**		**F**	**6.58**	**57**	**55**	**-2**	**-0.0309**	**3**	**52.93**
173	42.2		M	4.8	12	29	17	0.5144	6	26.53
178	63.5	20	M	19.43	4	2	-2	-0.1491	3	12.77
179	65.2	12	M	7.27	9	7	-2	-0.1129	2	17.72
180	30.9	12	M	17.33	0	1	1	0.1601	2	6.24
181	51.1	18	M	4.5	28	43	15	1.0889	2	13.78
182	67.9	20	M	7.53	4	4	0	0	2	6.25
183	67.7	16	M	33.04	36	37	1	0.0691	2	14.47
184	**77.7**		**M**	**92.02**	**52**	**52**	**0**	**0**	**2**	**11.98**
185	69.9	11	M	13.02	12	17	5	0.426	2	8.26
186	61.5		M	51.75	4	18	14	2.4195	2	5.78
187	**60.3**		**M**	**4.37**	**58**	**60**	**2**	**0.055**	**2**	**36.36**
188	79.8	12	F	0.33	13	23	10	0.9469	5	10.98
189	77.8	12	F	25.68	29	32	3	0.2022	3	12.03
190	64	12	M	97.32	7	9	2	0.0976	2	20.48
191	65.8	22	M	3.72	32	36	4	3.4762	2	1.11
192	37.6	15	M	5.85	51	55	4	0.4886	2	8.19
193	**49**	**18**	**M**	**2.6**	**60**	**57**	**-3**	**-0.0543**	**3**	**57.5**
194	61.3	18	F	23.01	48	52	4	0.4828	2	8.29
195	71.7	16	M	16.18	3	5	2	0.127	2	15.74

196	78.8	20	M	24.95	40	46	6	0.0892	2	67.27
197	**56.6**	**16**	**M**	**34.98**	**42**	**37**	**-5**	**-0.3812**	**2**	**13.1**
198	53.1	12	F	25.84	10	34	24	0.2633	6	81.69
199	67.1	12	M	48.07	49	56	7	0.7799	2	9
200	53.1	16	M	91.89	2	5	3	0.73	2	4.11
201	60.2	12	M	21.57	8	25	17	0.766	2	22
203	60.9	12	M	2.5	45	43	-2	-0.0396	2	50.46
204	63.6	18	M	9.9	3	7	4	0.0767	5	23.67
205	60.3	14	M	5.65	46	46	0	0	2	4.54
206	58	12	F	5.92	10	35	25	1.9649	2	12.72
207	29.5	12	M	83.64	5	9	4	0.361	2	11.08
208	79.2	10	F	9.67	30	49	19	2.0507	3	8.81
209	47.8	12	M	5.95	47	51	4	2.3856	2	1.68
210	**63.7**	**12**	**M**	**4.34**	**47**	**42**	**-5**	**-0.5355**	**2**	**9.34**
211	66.4	16	F	95.54	7	17	10	0.1408	5	73.38
212	**72.6**	**14**	**M**	**95.28**	**42**	**36**	**-6**	**-0.912**	**3**	**6.51**
213	**52.3**	**18**	**F**	**117.96**	**55**	**58**	**3**	**0.4959**	**2**	**6.05**
214	75.7	16	M	13.38	34	35	1	0.0778	2	12.9
215	51.2	12	M	4.18	50	54	4	0.1975	2	20.29
216	76.3	14	M	9.76	45	54	9	1.8497	2	5.1
217	85		M	0.53	10	34	24	1.8102	4	11.27
221	**59**	**16**	**M**	**57.6**	**33**	**20**	**-13**	**-2.9731**	**2**	**4.37**

Notes: Participants are sorted by an arbitrary ID number. Individuals bolded in red were excluded from the data analysis due to declines of 4 or more points within a year ($n = 4$). Individuals bolded in green were excluded from the data analysis because they had an initial *BNT* score of 52 and greater ($n = 8$).

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