LONG-TERM RECOVERY IN APHASIA

by

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Abstract

Language recovery was examined in 108 individuals with aphasia in the chronic phase of recovery who participated in various forms of aphasia treatment over extended periods of time. The *Western Aphasia Battery* (*WAB*) was administered at multiple time points and Aphasia Quotient (AQ) scores were used as a measure of language performance over time. As a group, the cohort showed an improvement of +6.52 AQ points, yielding an average rate of change of +4.07 AQ points per year. The rate of change was greatest at earlier times post onset (between three months and two years), and improvement was greatest for individuals with aphasia in the moderate severity range. Age, sex, and fluency did not have a significant effect on recovery. Education level had marginal predictive value in the direction of those with less education showing greater rate of improvement. These results suggest that language recovery continues during the chronic stage for individuals who are involved in some form of rehabilitation activity, especially in individuals with aphasia of moderate severity.

Introduction

Aphasia is an acquired language impairment typically resulting from damage to the language-dominant hemisphere of the brain. The disorder is characterized by word finding difficulties and deficits in language production and comprehension (Benson & Ardila, 1996; Goodglass, 1993; Nadeau, Rothi, & Crosson, 2000). Regarding the course of recovery in aphasia, it is well documented that the greatest extent of change occurs within the first three months after the neurological event, associated with a period of physiological restitution (Kertesz, 1984; Lomas & Kertesz, 1978; Teasell, Bayona, & Bitensky, 2005). The extent of recovery has been shown to be even greater with implementation of behavioral intervention (Basso, Capitani, & Vignolo, 1979; Robey, 1998), and rapid improvement in recovery during the acute phase is typically followed by more modest changes during the chronic period (Basso et al., 1979; Kertesz & McCabe 1977; Pickersgill & Lincoln, 1983; Vignolo, 1964). However, there is a large body of treatment literature that documents significant improvement during the chronic phase of recovery (for reviews, see Allen, Mehta, McClure, & Teasell, 2012; Moss & Nicholas, 2006; Robey, 1998). The majority of studies on aphasia recovery outcomes are conducted during the chronic phase with the intent of examining the therapeutic value of particular intervention approaches. Such studies are implemented over relatively short periods of time (e.g., weeks or months), and most are single-subject or small group designs. These studies provide a wealth of information regarding response to treatment, but do not offer a long-term perspective of aphasia recovery.

Kertesz and McCabe (1977) conducted one of the largest longitudinal aphasia recovery studies to date. They documented language performance using the *Western*

Aphasia Battery (*WAB*; Kertesz, 1982) in 93 individuals with aphasia. Performance was assessed initially within 45 days of stroke, and then follow up tests were completed at three time intervals: between 63 days to three months later, between three to six months later, and at six months and beyond, extending as far as 17 years for some individuals. Among those who were followed beyond three months post onset, some improvements in language skills were observed, providing early evidence of continued recovery in the chronic stage. Not all individuals continued to improve as shown by a subgroup with severe global aphasia who showed little improvement over time, even with therapy. In terms of predictive factors in long-term recovery, the authors found that age was negatively correlated with outcome, but that sex was not.

Another study of long-term recovery conducted by Hanson, Metter, and Riege (1989) followed the language performance of 35 individuals with chronic aphasia from three months post onset to nearly five years using the *Porch Index of Communicative Ability* (*PICA*; Porch, 1971). This study demonstrated that the greatest gains were seen within the first two years in individuals with mild and moderate levels of aphasia severity. After approximately two years of improvement, language performance tended to plateau or decline, particularly in individuals with mild and moderate levels of severity. Contrary to Kertesz and McCabe (1977), individuals in the most severe group showed steady gains in language performance over the course of five years. Predictive factors such as age, gender, education, or fluency were not explored. Although the results of Hanson and colleagues are difficult to compare to Kertesz and McCabe given that the assessment batteries were different, both studies present evidence for longitudinal recovery in aphasia past the acute stage.

In a smaller study of 12 individuals that focused on changes in lesion characteristics as well as language performance, Naeser et al. (1998) assessed individuals at time points between 2-12 months after insult, and again at 5-12 years. After five years or more post-stroke, significant improvements were demonstrated in naming abilities in the group as a whole, and in phrase length for a subset of those with nonfluent aphasia. Information was not reported regarding whether behavioral intervention occurred during the break between testing, so the changes may reflect response to treatment or natural recovery. In a controlled treatment study, Elman and Bernstein-Ellis (1999) considered the effects of group communication therapy in 24 participants with aphasia in the chronic stage, defined by the authors as greater than six months post onset. Several test batteries including the *WAB* were used to assess change in language performance. Participants demonstrated statistically significant gains in AQ score on the *WAB* when assessed half way through the 4-month treatment, and at the end of the intervention period. From pre-testing to post-testing, the group showed an average gain of 7.23 points on the *WAB*. Importantly, these gains were maintained when assessed one month later, suggesting lasting benefit of treatment in people with chronic aphasia.

A larger study conducted by Aftonomos, Applebaum, and Steele (1999) followed 60 individuals with aphasia, 46 of whom were seen at times greater than six months post onset, and considered to be in the chronic stage of recovery. The individuals were followed for an average of four and half months as they received community-based treatment. Individuals in the chronic stage improved on average +9.4 points on measures of language performance on the *WAB*, which was comparable to individuals in the acute stage who improved on average +8.0 points on the *WAB*. The results of their study suggested that significant improvements in both language skills and communicative function occurred during the chronic stage of recovery.

As noted above, attempts have been made to assess prognostic indicators of aphasia recovery. However, many studies either only tracked change in the acute stage, or included participants who were in the acute stage and extended their findings into the chronic stage, thus introducing the possible confound of spontaneous recovery. Of the studies available, predictors that were most often considered were sex, age, education level, time post onset, initial severity level, and fluency.

Literature examining the possible influence of sex on recovery largely suggests that there is not a significant difference between men and women. Numerous studies including Kertesz and McCabe (1977), Mimura et al. (1998), Plowman, Hentz, and Ellis (2012), and Sarno, Bounaguro, and Levita (1985) did not find any significant differences in performance in relation to sex. However, there has been some evidence to suggest otherwise. Pizzamiglio, Mammucari, and Razzano (1985) found language comprehension to improve to a greater extent in females with global aphasia as compared to males. Similarly, Basso, Capitani, and Moraschini (1982) noted that compared to males, females demonstrated greater recovery in oral expression.

Similar to sex, literature regarding the predictive value of age in the recovery of aphasia has presented mixed results (Plowman et al., 2012). Relating to patterns in later recovery, Kertesz and McCabe (1977) and Pickersgill and Lincoln (1983) found a trend toward younger individuals with aphasia showing greater improvement rates, but these trends were not statistically significant. Vignolo (1964) likewise observed that a greater percentage of younger participants improved relative to older patients, and Laska, Hellblom, Murray, Kahan, and Von Arbin (2001) witnessed better recovery rates in the younger versus older participants. Other findings, however, showed no predictive value of age in either the acute or chronic phase of recovery (Keenan & Brassell, 1974; Mimura et al., 1998).

With regard to educational level and aphasia, some research indicates that individuals with more severe deficits tend to have lower education levels (Connor, Obler, Tocco, Fitzpatrick, & Albert, 2001; González-Fernández et al., 2011; Smith, 1971). This suggests that those with higher educational attainment may be better protected from the repercussions of a stroke due to greater cognitive reserve. Largely, education has not been shown to influence the course of recovery in chronic aphasia (Connor et al., 2001; Plowman et al., 2012; Watila & Balarabe, 2015), however a recent study by Hillis and Tippett (2014) demonstrated that higher education levels were associated with better treatment outcomes in individuals first assessed within the acute stage.

Time post onset has been considered in several studies, however findings remain unclear. Kertesz and McCabe (1977) demonstrated that the greatest amount of language recovery occurred in the first two years, and continued beyond that time in some individuals. Hanson and colleagues (1989) also observed that the greatest amount of recovery occurred within the first two years, however performance in their participants was observed to plateau or decline past that point. In a review of single-subject research in individuals with chronic aphasia (> one year post onset), Moss and Nicolas (2006) found that response to treatment was not influenced by time post onset.

Studies assessing the influence of severity of aphasia on recovery typically based severity on initial performance in the acute stage. (Demeurisse et al., 1980; Jung, Lim, Kang, Sohn, & Paik, 2011; Keenan & Brassell, 1974; Kertesz & McCabe, 1977; Laska et al., 2001; Pedersen, Vinter, & Olsen, 2004). Information regarding whether or how severity predicts recovery in the chronic stage is scarce. However, the previously mentioned study by Hanson and colleagues (1989) began observation of language performance in the chronic stage of recovery and found that the most severe group in the study made the most change. Conversely, Aftonomos et al. (1999) found that individuals with aphasia of moderate severity demonstrated an average increase of 12.4 AQ points on the *WAB*, considerably greater than both the mild and severe groups. Basso, Capitani, and Vignolo, (1979) reported similar findings, suggesting that the greatest amount of recovery may occur in individuals who demonstrate a moderate degree of impairment.

With regard to aphasia profiles, some researchers have attempted to characterize recovery patterns by aphasia type (Aftonomos et al., 1999; Bakheit, Shaw, Carrington, & Griffiths, 2007; Kertesz & McCabe, 1977). When grouped by aphasia type, two studies suggested that individuals with Broca's aphasia tended to demonstrate the greatest amount of change (Kertesz & McCabe, 1977; Bakheit et al., 2007). Because few studies include equal distribution across aphasia types, more often the aphasia profiles have been divided into broad "fluent" and "nonfluent" categories to examine recovery. Nonfluent aphasias include Broca's, global, mixed transcortical, and transcortical motor, and are associated with damage to frontal brain regions. Fluent aphasias include anomic, conduction, transcortical sensory, and Wernicke's aphasia, and are associated with posterior damage. A study in 1979 by Sarno and Levita followed recovery within the first year after stroke for 20 individuals classified as either fluent or nonfluent. They found that those with nonfluent aphasia demonstrated improvement throughout the year, whereas those with fluent aphasia showed the greatest change within the first few months post onset, and then largely no change in the second half of the year. In contrast, the results of Basso and colleagues (1979) did not support better outcomes in nonfluent aphasia types compared to fluent aphasia types at any point in time. As a whole, the influence of fluency as a predictor of outcome is mixed at this time.

In summary, relatively few studies have examined long-term recovery outcomes in aphasia, and the expectations regarding recovery rate and prognostic indicators are not entirely clear. The current study was intended to address this issue by examining available longitudinal data from the *Western Aphasia Battery* (*WAB*; Kertesz, 1982) in a large cohort. This retrospective study allowed us to examine language performance over time.

The *WAB* is a widely used standardized test designed to assess the nature and severity of aphasia. Performance on measures of speech production and auditory comprehension yield an aphasia quotient, and the overall profile allows discernment of aphasia type. Specifically, the aphasia quotient (AQ) is calculated from performance on several subtests including spontaneous speech, auditory verbal comprehension, repetition, and naming. The AQ score provides an index of aphasia severity on a 100-point scale, with a lower score indicating greater impairment in these areas that the subtests address. Individuals with AQ scores greater than 93.8 are not considered to have aphasia according to the *WAB* (Kertesz, 1982).

Although the *WAB* has acknowledged limitations (Hula, Donovan, Kendall, & Gonzalez-Rothi, 2010), it is one of the most commonly used standardized measures of overall language performance in aphasia. Standardization of the test began in the early

1970s, and the psychometric properties were reported by Kertesz in 1979 and Shewan and Kertesz in 1980. The later publication provided data from a sample of 150 people with aphasia. Internal consistency was high, with a Chronbach's alpha value of 0.905. Correlation coefficients for inter-judge reliability and intra-judge reliability were above 0.9, and for test-retest reliability in 38 individuals, the Pearson's r value was 0.968. The *WAB* was shown to have good construct validity (Pearson's $r = 0.964$, $p < .001$) when correlated with the *Neurosensory Center Comprehensive Examination for Aphasia* (*NCCEA*; Spreen & Benton, 1977), a test battery that similarly examines aspects of language. Lastly, face validity and content validity were considered to be adequate according to the authors. Minor revisions were made to the *WAB* in 2007, however new standardization was not completed for the resulting *WAB-Revised*.

Although the test-retest reliability of the *WAB* is high, limited data are available relative to variability between tests. Specifically, the standard error of measurement was not provided in the early standardization data, nor is it available in the test manual for the *WAB* or the *WAB-R*. In analyzing test-retest reliability in 22 participants at a year interval, Kertesz (1979) reported a mean difference between tests of 0.9 points (standard deviation not reported). In a second cohort of 35 individuals assessed at roughly two and four years post onset, the mean difference between tests was 0.12 points (standard deviation not reported). Although test-retest reliability was high for both cohorts (Pearson's $r = 0.992$ and $r = 0.97$, $p < .01$ respectively), due to the lack of information regarding variance in the difference scores, it was not possible to calculate standard error of measurement. In the Shewan and Kertesz 1980 study, test-retest reliability was measured from a period anywhere between 6 months - 6.5 years. Shewan and Kertesz reported a mean difference score of 5.62 points within their cohort (no standard deviation reported), again making it impossible to calculate standard error of measurement for the data. This large observed change in test scores may have reflected language improvement because some of the individuals in the cohort were receiving treatment. To our knowledge, information regarding standard error of measure is still lacking, however, a more recent study by Pedersen, Vinter, and Olsen (2001) administered the *WAB* three and a half months apart, and found a mean change of 1.42 (SD = 8.27) with a Pearson's r correlation coefficient of 0.96. Using this information, the calculated standard error of measurement was 1.65. In the absence of available data, this appears to be the closest estimate of test-retest differences based on chance.

In the current study, language performance over time was observed in a large group of individuals with aphasia. Predictive factors such as sex, age, education, fluency, time post-onset, and severity were explored in order to gain information to aid in the prognosis of stroke recovery. We conducted a retrospective analysis of data collected from periodic speech and language evaluations administered to individuals participating in the Aphasia Research Project and the Clinic for Adult Communication at the University of Arizona over the past 25 years. The data allowed examination of recovery over a long period of time in individuals who participated in aphasia therapy at this facility. Because information regarding the amount and type of treatment were not consistently available across the cohort, this study simply seeks to address the question of long-term outcomes in individuals who received language intervention.

Methods

Data were available for 144 adults with a history of acute onset of aphasia (i.e not progressive aphasia). All individuals partook in aphasia treatment over various periods of time and completed more than one *WAB* assessment. All tests were the original version of the *WAB*. Based on their initial performance on the *WAB*, those who received an AQ score greater than 93.8 were excluded (*n* = 8). To account for physiological restitution, those who received an initial evaluation earlier than three months post onset were excluded (*n* = 4). Furthermore, time post onset was limited to 10 years, and two individuals were excluded because they fell outside of this time period. Thus, inclusion criteria yielded adults who were seen at least three months post onset, but not greater than 10 years.

Etiology consisted of single focal brain injury, and eighteen individuals were excluded due to pre-existing or comorbid neurological/health issues including multiple strokes, cognitive impairment, dementia, extensive traumatic brain injury, encephalopathy, or cancer. There was insufficient requisite demographic information available for four individuals; therefore, they were not included in the cohort. All individuals with available demographic information that fit the inclusion criteria were included in analysis, leaving a final number of 108 participants.

Participant Characteristics

A summary of participant characteristics is included in Table 1. Of the 108 participants, the majority were male (*n* = 78). Mean age at time of injury was 59.3 years (range = 22.5 - 82.6 years), and all participants completed at least nine years of education (*M* = 14.8; *SD* = 2.7). Average time post-onset of initial administration of the *WAB* was

22.9 months, with the earliest administration at 3.0 months post onset, and the latest at 10 years post onset. Approximately 52% of the cohort received their initial assessment within the first year after onset, and the remaining were at times greater than one year. Several individuals were seen at particularly long times post onset, with eleven receiving initial assessment more than four years past their date of insult. Due to the heterogeneity in individuals with aphasia, therapy was individualized and took differing amounts of time to complete. The amount of treatment each participant received was estimated to have been at least one hour per week during the course of treatment, but the total number of hours of treatment was not available. Participants received either individual treatment, group treatment, or both. Intervals between administrations of tests was not consistent for each participant. The average time between test administrations was 1.2 years, ranging from 2.4 months to 5.9 years. Across the cohort, the number of *WAB* tests administered per individual varied from 2 - 13, with an average of 3.68 (*SD* = 2.26).

A wide range of severity levels was represented in the cohort. Initial AQ score from the *WAB* ranged from 4.5 to 93.8 points. Slightly more than half of the participants (*n* = 68) were considered to be fluent at initial assessment according to their performance on the *WAB*. Within the fluent group, more than half were classified as having anomic aphasia (40 of 68 individuals). Within the nonfluent group, 34 of 40 individuals were classified as having Broca's aphasia. Handedness was available for 99 individuals. Of those, 87 were right-handed, 11 were left-handed, and one self-reported as being ambidextrous. Additional demographic information for individual participants is included in Appendix A.

Data Analysis

A paired samples t-test was performed to compare initial scores and final scores for the cohort as a whole to determine whether there was a statistically significant change in performance. To examine overall change in severity, the final AQ score was subtracted from the initial AQ score for each individual. Differences in AQ change were analyzed for three sub-groups based on initial severity by using a one-way analysis of variance (ANOVA). These calculations were done using SPSS Version 23.

A general linear model (GLM) was used to examine the predictive value of sex, age at evaluation, education, fluency, time post onset in years, and initial AQ score. A linear mixed effects model was used with a random intercept for each participant, and fixed factors of age at the time of testing (centered around the mean), time post onset and logarithmic time post onset (centered around the mean), aphasia quotient and aphasia quotient squared (centered around the mean), fluency, education, and sex. Improvement rate by year was considered for each interval between *WAB* assessments. These statistics were carried out using R 3.2.4 for Macintosh.

Table 1. Participant characteristics (N = 108)

Characteristics	**Mean**	**SD**	**Range**	**Classification**	**N**
Gender				Male Female	78 30
Education (years)	14.8	2.7	9 - 20		108
Age at Stroke (years)	59.3	13.7	22.5 - 82.6		108
TPO at Initial *WAB* (months)	22.9	26.1	3.0 - 120.5		108
Initial Severity (AQ score)	61.1	25.9	4.5 - 93.8		108
Initial Fluency			Fluent	Anomic (40) Conduction (19) Wernicke's (9)	68
			Nonfluent	Broca's (34) Global (4) TCM (2)	40

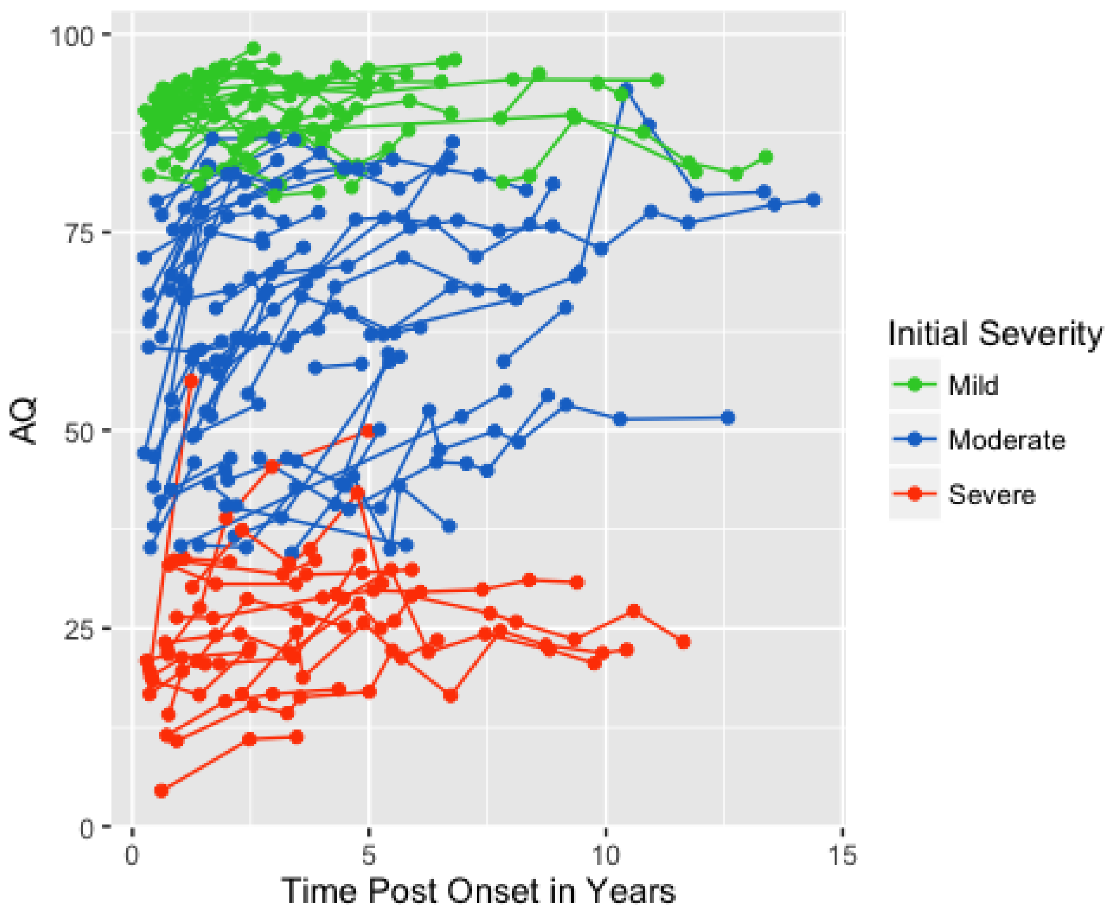
Note. TPO = time post onset; TCM = transcortical motor

Results

All AQ scores for each individual were plotted against time post onset in years and are displayed in Figure 1. Although the *WAB* does not specify cutoff scores for specific severity ranges, visual analysis of data suggested mild, moderate, and severe subgroups. Initial AQ scores in the lower range tended to become asymptotic just below 34 points. Similarly, the change in *WAB* scores for individuals in higher ranges appear to flatten as they reach the ceiling of 100 possible points. For the purposes of this study, these observations were used to create boundary levels for classification of the severity of aphasia. Individuals with an initial AQ score less than 34 points were classified as “severe,” those between 34 and 79.9 points were classified as “moderate,” and finally those with scores above 80 points were classified as “mild.” Using this classification system, 38 individuals were classified as having mild aphasia, 50 as moderate aphasia, and 20 as severe aphasia.

Overall, the average amount of change in AQ score between initial and final assessment was +6.52 points (SD = 8.42). The mild group improved on average +2.06 AQ points (SD = 2.82), which was a significant increase compared to their initial scores ($t(37) = 3.77$, $p = .001$). For the moderate group, AQ scores improved on average +9.96 points (SD = 9.10), which was also a significant improvement over initial scores ($t(49) = 7.74$, $p < .0001$). The severe group improved by +6.39 (SD = 9.62), also a significant gain over initial scores ($t(19) = 2.97$, $p = .008$). The improvement scores across the three sub-groups confirmed the differential effect of severity on gain ($F(2, 107) = 11.37$, $p < .001$). Planned Hochberg’s GT2 post-hoc tests demonstrated that change in the moderate group was statistically significantly greater compared to the mild group ($p < .001$), but not in relation to the severe group (p = .227). The magnitude of change was not significant between the mild and severe group (p = .126).

Figure 1. Aphasia quotient change over time



Note. Mild severity was defined as an AQ score between 80-100 points, moderate was between 34-79.9 points, and severe was between 0-33.9 points.

Improvement scores were also examined relative to initial fluency categorization. Forty individuals with a nonfluent aphasia profile (Broca's, global, or transcortical motor aphasia) improved on average +10.23 AQ points (*SD* = 10.19). The fluent aphasia profile group (Anomic, Conduction, or Wernicke's aphasia) showed an average improvement of +4.37 (*SD* = 6.32). An independent sample t-test showed that the difference between the means of the fluent and nonfluent group were not significant (t(106) = -0.288, *p* = .624).

In addition to change in performance overall, a measure of change per year was calculated by taking the change in AQ scores by the time interval in years for consecutive pairs of *WAB* tests. A graph of change in AQ per year as a function of time-post onset is represented in Figure 2. A locally weighted regression line was applied to the data in order to analyze the pattern. As shown in Figure 2, a decreasing exponential model demonstrated that the greatest positive gains occurred in the first several years, and then approached zero in the years following. This was confirmed through comparison of the average yearly change in AQ score in the first two years (*M* = 5.23, *SD* = 8.08) and average yearly change at two years and beyond (*M* = 1.09, *SD* = 6.97). Although yearly change in AQ score was still positive in the later years, the magnitude of change was less.

Change in performance per year was also measured against first AQ score (i.e. severity level) for consecutive pairs of *WAB*s. Again, a locally weighted regression line was applied in order to assess the pattern in the data. As demonstrated in Figure 3, the data followed a negative quadratic function, in that scores in the middle range of AQ severity showed greater amounts of change per year compared to those in the low or high range. Individuals with moderate levels of severity improved on average 5.26 AQ points per year (*SD* = 6.16), which was greater than both the mild group (*M* = 2.26, *SD* = 5.21) and the severe group (*M* = 4.51, *SD* = 10.32). Furthermore, it was observed that those in the moderate severity range continued to show the most gains in performance at greater times post onset. Beyond two years post onset, the mild and severe groups showed average yearly improvement rates that were close to zero, whereas the moderate group showed a rate of +2.39 AQ points per year. Comparison of the average change per year within the first two years and the later years is displayed in Table 2.

Figure 2. Improvement rate in AQ per year by time post onset

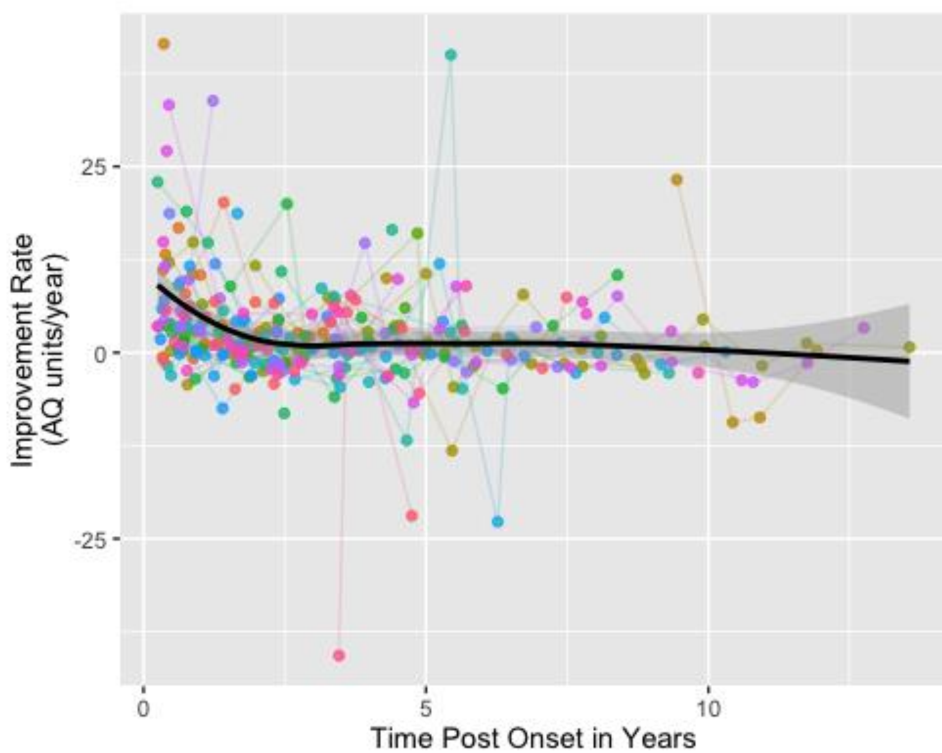
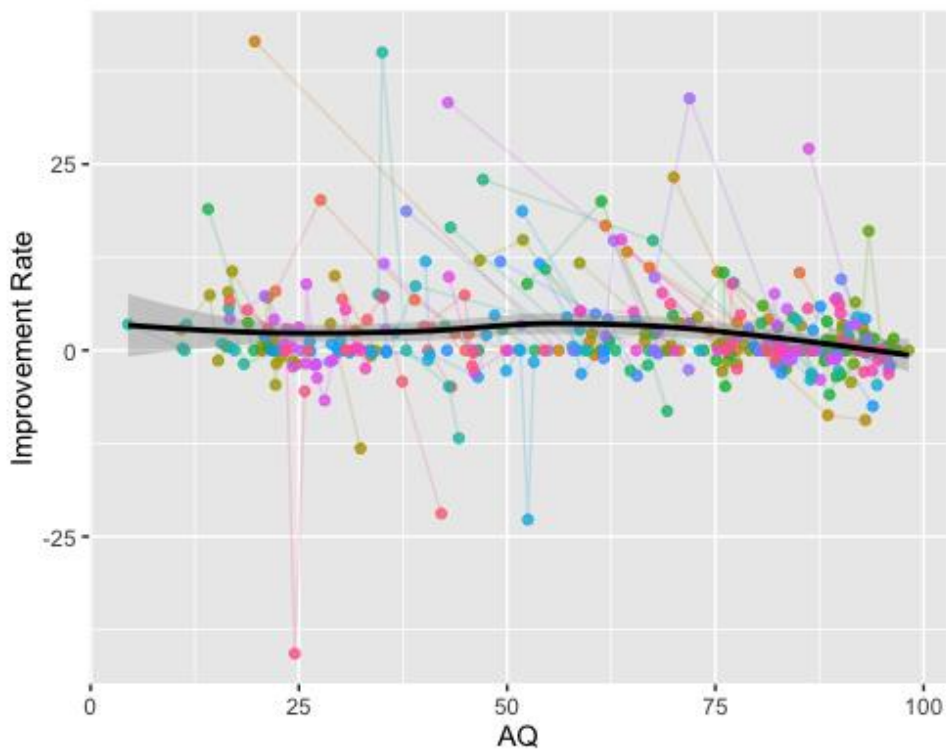


Figure 3. Improvement rate in AQ per year by initial AQ score



Examining the outcome in individual patients, 89 out of the total 108 participants showed a positive change in AQ score over the course of their treatment. Ideally, the magnitude of change would be evaluated against the standard error of measurement (SEM) for the *WAB*. As discussed previously, this information is lacking in the standardization of the *WAB*. Using the SEM calculated from Pedersen and colleagues (2001), individual changes in test scores greater than 1.65 would be considered reliable. Applying this criteria, 77 individuals in the cohort improved beyond test-retest variability. Only ten participants demonstrated a decline in scores that were greater than a 1.65 point change from their initial score. These results largely support the finding that significant change occurred in the period of chronic recovery of aphasia.

Table 2. Average yearly change in AQ by severity level with relation to TPO

	Change in Aphasia Quotient (SD)	
	Subgroup 1: TPO: < 2 years	Subgroup 2: TPO: 2 years – 10 years
Mild	2.17 (5.25) points	0.14 (3.89) points
Moderate	8.33 (8.56) points	2.39 (8.21) points
Severe	5.27 (9.55) points	0.14 (7.72) points

Note. This table shows the average yearly change for two groups. Subgroup 1 included individuals who were assessed between 3 months and 2 years. Subgroup 2 included individuals who were assessed between 2 years and 10 years.

A general linear model was used to assess the relationships between the dependent variable (change in AQ) and the following independent variables: sex, age at evaluation, education level, fluency profile, time post onset, and initial AQ score. For time post onset, both a linear and an exponential fit were included in the model based on the pattern observed in Figure 2. Additionally, the shape of the locally weighted regression line observed in Figure 3 supported the use of both a linear and a quadratic fit for the change in AQ score. Both were included to allow for flexibility within the model. The linear mixed effects model showed that time post onset, AQ score, and education were significant predictors of positive change in AQ score over time (Table 3). Factors resulting in better outcomes included earlier time post-onset, AQ scores in the mid-range, and lower education level. Sex, age, and fluency were not shown to be significant predictors of change.

Table 3. Analysis of predictor variables on improvement rate of Aphasia Quotient

Independent Variable		**Change in Improvement Rate per Unit**	
	$\widehat{\beta}$	*F*	*p value*
Sex	- 0.037	.021	0.6506
Age	- 0.003	2.90	0.0931
Education	- 0.028	4.28	0.0448*
Fluency	+ 0.146	1.57	0.2129
Time post onset -linear function	- 0.003	0.03	0.8624
Time post onset -exponential function	+ 0.025	15.71	0.0001**
AQ -linear function	- 0.006	7.13	0.0087**
AQ -quadratic function	- 1.682	6.23	0.0146*

* = significant at $p < .05$ ** = significant at $p < .01$

Discussion

In this study of language recovery in a large cohort of individuals with chronic aphasia, AQ scores improved significantly over time for the group as a whole with an average increase of +6.45 points across all participants. Individuals with moderate aphasia demonstrated the greatest improvement with an average overall change of +9.96 AQ points, compared to those with mild aphasia who improved on average +2.06 points, and those with severe aphasia who improved on average +6.39 points. These results are consistent with the findings of Aftonomos and colleagues (1999), as well as Basso et al. (1979). Aftonomos et al. (1999) found that participants with moderate aphasia demonstrated an average increase of 12.4, which was considerably greater than the severe (M = 6.7) and mild (M = 5.8) groups. Basso et al. (1979) noted that of the individuals who improved, the greatest percentage had moderate aphasia. When examining recovery after two years post onset in the current study, those in the moderate severity range continued to improve at a rate of about three points per year. In contrast, individuals with mild and severe aphasia show minimal improvement after two years.

Predictors for recovery that were statistically significant included severity, time post onset, and education. As stated, individuals with moderate levels of severity demonstrated the greatest improvement rate. Time post onset exhibited a negative exponential pattern indicating that a greater amount of change occurred at earlier times post onset, and then became less robust beyond two to three years. Finally, education was negatively correlated with recovery rate, in that those with lower levels of education demonstrated greater rates of change on the *WAB*. No other predictors examined were significant according to the model employed.

In assessing recovery pattern in relation to initial fluency, there was no difference in overall change in performance for individuals who were classified as fluent versus nonfluent. This finding was consistent with Basso and colleagues' (1979) who indicated that both fluent and nonfluent individuals followed the same course of improvement over time, but was in contrast with Sarno and Levita (1979) who demonstrated greater improvement rates in individuals with nonfluent aphasia.

It is not surprising that individuals in the moderate severity range showed the greatest amounts of improvement because their spoken language abilities were not so severely limited that they were unable to progress. Furthermore, these individuals had plenty of room to improve on the *WAB* before reaching ceiling. In contrast, those with mild aphasia often did reach a ceiling, and were limited in the amount of improvement that could be made. For those with mild aphasia whose primary residual deficits were lexical retrieval difficulty, improvement might be more apparent if these participants were examined over time using a more rigorous test of lexical retrieval compared to the *WAB*, such as *the Boston Naming Test* (*BNT*; Kaplan, Goodglass, & Weintraub, 1983). Individuals with severe aphasia at the outset often have spoken language production impairments that persist. This includes those with marked impairment of motor speech control or those with severely paraphasic speech as in Wernicke's aphasia. Although these individuals can make improvements in comprehension and highly structured tasks such as single word repetition, they are often limited in the ability to regain spoken language skills.

The finding that education was a negative predictor for improvement was surprising given that much of the current literature has found education to be a positive predictor of change (González-Fernández et al., 2011), or not significant (Lazar, Speizer, Festa, Krakauer, & Marshall, 2008; Plowman et al., 2012). Importantly, many of the studies that assessed education as a predictor began assessment within the acute stage. Generally it is expected that individuals who are highly educated demonstrate greater resiliency from neurological damage, suggesting that education serves as a proxy for cognitive reserve (Roe, Xiong, Miller, & Morris, 2007; Staff, Murray, Deary, & Whalley, 2004). The results from the current study, however, showed that lower levels of education lead to greater improvements in language performance during the chronic stage. We do not have a good explanation for this finding, however it could be the case that those with higher education benefitted from the outset due to greater cognitive reserve. In contrast, those with less education may have showed greater benefit from intervention in the chronic stage. Perhaps these individuals gained skills from intervention that were naturally occurring in individuals with more education. In other words, individuals with lower levels of education may have benefited from treatment regarding strategies that those with higher levels of education naturally employed.

The current study was limited in that the nature and amount of treatment was not controlled, and participants received varying amounts and types of treatment. It is important to keep in mind that the *WAB* AQ does not include information about written language processing, nor is the test designed to assess functional communication, therefore it not necessarily the case that individuals cannot benefit from treatment at later times post onset. Furthermore, the *WAB* AQ score, is heavily weighted toward measures of spoken output. As such, though individuals with severely limited spoken output might show gains in functional communication through participation in treatment, this change may not be reflected on the standardized *WAB* assessment. Nevertheless, results of this study indicate that significant gains in comprehension and production of spoken language can be made in the years following brain damage that results in aphasia. Other communication and language skills such as reading and writing were not examined in this study because they were not sampled in a consistent manner in this cohort. Future studies would benefit from considering other aspects of improvement, and from adding additional tests for comprehension and production in this population. Finally, we acknowledge that information regarding location and extent of lesion is an important prognostic indicator that was not included in this study.

To our knowledge, this study provides the largest data set examining language recovery over many years in individuals with aphasia. Given that the participants were engaged in individual or group treatment to some extent, the results are most appropriately generalized to individuals who similarly continue to receive some sort of language treatment. Our results demonstrate that recovery rate is greater at earlier times post onset extending to the first two years, and shows a decelerating time course. Furthermore, recovery rate is greater for patients whose aphasia is moderate in severity. The outcomes are encouraging with regard to the potential for continued improvement in language skills long after the acute phase of recovery.

Appendix A: Individual data

Sorted from greatest positive gain to greatest decline in aphasia quotient score.

ID	Age	Edu.	Sex	Hand	Severity	Fluency	TPO-m at Initial Test	TPO-m at Final Test	Total Time Between Test	Initial AQ	Final AQ	AQ Change
187	47.4	12	F	R	Mod	NF	5.5	61.4	55.9	42.9	82.9	40.00
111	22.8	16	M	R	Sev	NF	4.3	14.9	10.6	19.7	56.2	36.50
146	54.5	11	M	R	Mod	Fl	3.0	36.4	33.4	47.1	81	33.90
138	67.8	12	F	R	Mod	Fl	18.5	106.5	88	52.4	81.1	28.70
102	29.4	12	M	R	Sev	NF	8.9	59.9	51	22.2	49.9	27.70
156	51.0	12	F	R	Mod	NF	25.7	67.9	42.2	36.6	59.3	22.70
122	34.2	14	M	L	Mod	NF	23.7	172.6	148.9	58.7	79.1	20.40
176	57.5	12	F	R	Mod	NF	5.5	18.4	12.9	37.9	57.9	20.00
109	56.3	14	M	R	Mod	NF	4.6	36.7	32.1	64.4	84.1	19.70
179	22.5	12	M	R	Mod	NF	12.3	94.6	82.3	35.4	54.9	19.50
173	68.4	16	F	R	Mod	NF	15.3	94.2	78.9	49.2	67.6	18.40
200	42.2	12	F	L	Mod	NF	44.1	81.2	37.1	68.6	86.4	17.80
148	35.3	12	F	R	Mod	NF	52.8	64.8	12	43.2	59.7	16.50
181	78.3	10	F	R	Mod	NF	9.6	18.9	9.3	67.7	83.4	15.70
123	62.0	16	M	R	Mod	NF	5.4	22.6	17.2	46.7	61.2	14.50
209	44.3	12	M	R	Mod	NF	54.8	105.2	50.4	40	54.4	14.40
192	60.6	18	F	L	Mod	Fl	3.0	47.6	44.6	71.8	85	13.20
105	50.7	18	M	R	Mod	Fl	4.2	18.2	14	67.1	80.1	13.00
193	63.3	12	M	R	Mod	NF	4.2	13.5	9.3	63.7	75.3	11.60
121	55.8	12	M	L	Sev	NF	11.1	125.2	114.1	10.8	22.3	11.50
196	42.3	14	M	R	Mod	Fl	21.2	47.2	26	58.8	70.1	11.30
184	45.6	16	F	R	Mod	Fl	4.6	15.6	11	35.2	45.9	10.70
115	53.7	17	M	R	Mod	Fl	113.2	160.1	46.9	70	80.1	10.10
165	61.2	16	M	R	Mod	Fl	19.9	26.3	6.4	51.8	61.7	9.90
147	47.9	12	M	R	Mod	Fl	7.4	35.8	28.4	77.2	86.9	9.70
211	57.3	14	M	L	Sev	NF	27.7	44.7	17	16.7	26.1	9.40
182	49.3	14	F	R	Sev	NF	4.3	53.7	49.4	16.7	25.2	8.50
144	66.8	16	F	R	Mod	NF	29.3	73.0	43.7	54.6	63	8.40
124	51.2	16	M	R	Mild	Fl	3.2	30.6	27.4	90.3	98.2	7.90
158	53.1	20	M	L	Mild	Fl	5.9	133.0	127.1	86.5	94.2	7.70
167	62.8	18	M	R	Mod	Fl	9.8	33.3	23.5	53.9	61.6	7.70
160	58.3	12	M	R	Mod	Fl	21.1	43.3	22.2	65.4	73.1	7.70
128	55.8	12	M	L	Mod	Fl	60.4	112.3	51.9	62.1	69.4	7.30
172	58.0	13	F	--	Mod	NF	16.8	41.4	24.6	35.5	42.8	7.30
132	46.2	16	M	R	Mild	Fl	55.6	70.0	14.4	80.7	87.9	7.20
106	67.2	20	M	R	Mod	Fl	7.5	12.6	5.1	61.8	69	7.20
154	74.1	12	M	--	Sev	NF	7.3	41.6	34.3	4.5	11.3	6.80
194	58.4	16	F	R	Mod	Fl	94.1	109.8	15.7	58.7	65.5	6.80
205	64.1	19	M	R	Mod	Fl	9.9	38.3	28.4	69.6	76.3	6.70
189	47.2	12	M	R	Mild	Fl	4.9	7.8	2.9	86.2	92.7	6.50
203	41.7	12	M	R	Mild	Fl	4.8	39.9	35.1	86.1	92.2	6.10
114	69.9	12	F	R	Mod	Fl	10.4	19.6	9.2	75.3	81.3	6.00
180	62.0	18	M	R	Mod	Fl	40.7	87.5	46.8	61.8	67.7	5.90

155	76.3	13	M	R	Sev	NF	8.6	52.3	43.7	11.5	17.3	5.80
195	64.7	14	M	A	Mild	Fl	93.3	103.1	9.8	89.4	95	5.60
141	60.6	12	M	R	Sev	NF	9.1	12.6	3.5	14.1	19.6	5.50
142	70.1	17	M	R	Mod	Fl	6.0	80.4	74.4	78.9	84.4	5.50
130	74.0	18	M	R	Mild	Fl	8.4	69.4	61	89.6	95	5.40
164	34.4	16	F	R	Mod	NF	32.1	150.9	118.8	46.5	51.6	5.10
104	54.1	16	M	R	Mild	Fl	12.1	17.9	5.8	85.1	90.1	5.00
116	57.2	16	M	R	Sev	NF	51.6	57.5	5.9	29.3	34.2	4.90
166	52.0	16	M	R	Sev	NF	11.2	112.7	101.5	26.4	30.8	4.40
204	74.5	16	M	R	Mod	NF	13.2	24.0	10.8	78	82.3	4.30
112	68.7	11	M	R	Mod	Fl	13.0	37.2	24.2	66.5	70.7	4.20
151	74.9	16	M	R	Sev	NF	5.2	29.8	24.6	18.4	22.6	4.20
174	57.8	12	F	L	Mild	Fl	4.4	11.6	7.2	89.6	93.8	4.20
175	50.1	16	M	R	Mild	Fl	8.0	13.1	5.1	90.1	94.2	4.10
113	77.5	16	M	R	Mild	Fl	9.8	35.8	26	92.7	96.8	4.10
190	62.0	16	M	R	Mod	Fl	41.5	62.7	21.2	46.1	50.1	4.00
101	64.6	12	M	R	Mod	NF	7.1	23.5	16.4	41	45	4.00
149	82.6	12	M	--	Mod	NF	9.7	24.8	15.1	42.5	46.5	4.00
177	65.9	17	M	L	Mild	Fl	11.5	53.7	42.2	91	95	4.00
126	70.0	19	M	--	Mild	Fl	47.6	78.3	30.7	90.2	94	3.80
133	36.7	14	F	R	Mild	Fl	8.7	81.7	73	93	96.8	3.80
145	70.3	16	M	R	Mod	Fl	16.0	31.9	15.9	49.5	53.3	3.80
185	73.0	18	F	R	Mild	Fl	7.9	48.6	40.7	83.6	87.2	3.60
202	76.6	11	M	R	Mild	Fl	6.6	59.5	52.9	90.3	93.8	3.50
153	74.6	14	M	R	Mod	Fl	40.5	80.3	39.8	34.5	37.9	3.40
186	58.7	13	M	L	Mild	Fl	93.7	47.1	-46.6	81.3	77.5	3.20
110	64.9	16	M	R	Mod	Fl	32.8	160.5	127.7	74.3	84.5	3.2
134	40.2	12	M	R	Sev	NF	4.7	29.4	24.7	18.9	22	3.10
201	39.7	20	F	R	Mild	Fl	8.8	45.9	37.1	90	93.1	3.10
127	48.8	18	M	R	Mild	Fl	12.5	17.9	5.4	91.8	94.7	2.90
103	70.0	12	F	--	Mod	Fl	24.1	39.1	15	43.7	46.5	2.80
183	55.7	16	M	R	Mild	Fl	8.0	32.2	24.2	91.8	94.4	2.60
137	37.1	15	M	R	Mild	Fl	5.7	13.1	7.4	88.4	90.8	2.40
169	62.3	16	M	R	Mild	Fl	3.9	41.7	37.8	87.6	89.7	2.10
136	76.4	16	M	R	Mild	Fl	7.3	39.4	32.1	92.4	93.9	1.50
178	60.0	18	M	R	Mod	Fl	28.3	99.9	71.6	79	80.3	1.30
198	77.2	16	M	R	Mild	Fl	18.7	30.6	11.9	82.5	83.4	0.90
171	77.7	20	M	R	Sev	NF	3.6	9.0	5.4	20.9	21.7	0.80
131	51.2	12	M	R	Mild	Fl	8.4	51.7	43.3	87.8	88.5	0.70
108	65.0	12	M	--	Mod	NF	4.1	29.0	24.9	60.5	61.2	0.70
168	77.9	18	M	R	Mild	Fl	7.7	64.5	56.8	93.2	93.8	0.60
162	42.7	14	M	R	Mod	NF	46.3	58.0	11.7	57.9	58.4	0.50
210	73.7	16	M	R	Sev	NF	15.1	63.2	48.1	30.2	30.7	0.50
118	82.5	16	F	--	Mild	Fl	5.8	16.6	10.8	91.9	92.1	0.20
119	65.7	16	F	R	Sev	NF	18.4	117.2	98.8	20.5	20.6	0.10
188	58.8	20	M	R	Sev	NF	8.3	139.7	131.4	23.2	23.3	0.10
107	63.0	16	M	R	Sev	Fl	10.6	46.3	35.7	33.6	33.6	0.00
163	77.1	12	F	R	Sev	NF	13.1	24.6	11.5	33.8	33.4	-0.40
129	57.7	10	F	--	Mild	Fl	56.8	80.7	23.9	90.6	90	-0.60
197	71.8	14	M	R	Sev	Fl	9.2	70.8	61.6	33	32.4	-0.60

120	73.5	16	M	R	Mild	Fl	9.4	52.0	42.6	91.3	90.4	-0.90
206	62.0	16	M	L	Sev	NF	41.5	77.3	35.8	24.5	23.5	-1.00
207	50.8	12	M	R	Mild	Fl	4.2	16.8	12.6	82.2	81.1	-1.10
199	42.4	18	F	R	Mild	Fl	117.8	124.0	6.2	93.8	92.4	-1.40
139	80.1	16	F	--	Mod	Fl	19.7	33.1	13.4	75.1	73.6	-1.50
135	71.4	18	F	R	Mild	Fl	8.4	42.5	34.1	88.4	86.6	-1.80
143	60.0	9	M	R	Mod	Fl	29.9	33.1	3.2	69.2	67	-2.20
161	69.6	14	F	R	Mild	Fl	9.2	54.1	44.9	92	89.6	-2.40
125	75.6	12	F	R	Mild	Fl	25.4	37.4	12	83.5	81	-2.50
170	58.8	20	M	R	Mild	Fl	11.1	47.1	36	82.6	80.1	-2.50
100	61.8	20	M	R	Mod	Fl	19.4	26.2	6.8	43.3	40.5	-2.80
157	63.0	12	M	R	Mild	Fl	47.8	57.0	9.2	86.4	83.4	-3.00
140	77.0	12	M	R	Mild	Fl	11.0	64.8	53.8	89.5	85.5	-4.00
152	49.4	16	M	R	Mild	Fl	28.9	142.8	113.9	87	82.6	-4.40
159	77.5	16	M	R	Mod	NF	23.6	69.3	45.7	40.5	35.5	-5.00

Note. TPO = time post onset; F = female; M= male; Sev = severe; Mod = moderate; NF = nonfluent; Fl = fluent; AQ = Aphasia Quotient;
“-- "indicates that data was not available

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