Continuous Performance Test Results following Neurofeedback and the Efficacy of Frequency Optimization using Bipolar Training Montages

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ABSTRACT

Continuous Performance Test measurements are presented for the time frame of 2006 to 2012, a period of rapid evolution in neurofeedback training protocols with the introduction of infra-low frequency training. The objective was to assure that outcomes were not compromised in any way by the change in training procedures.

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BACKGROUND

Continuous performance tests have been performed at the EEG Institute (and its predecessor, EEG Spectrum) as a standard assessment tool for progress in neurofeedback since 1990. Because of its long track record, this test acquired heightened importance as training protocols underwent rapid evolution with the introduction of infra-low frequency training in 2006. With the introduction of infra-low frequency training, priorities in training shifted from a left-hemisphere and pre-frontal bias to a right-hemisphere and parietal bias. Correspondingly, there was a shift from a focus on executive function to a focus on arousal regulation, affect regulation, and autonomic regulation with the new right-hemisphere priority. For that reason, it was important to ascertain that progress in enhancing executive function was not compromised with the shift in clinical priorities. This paper is a follow-up to a previous paper using bipolar, intra and inter-hemispheric sites on a wide array of symptoms --including attention deficit disorder (Putman et al., 2005). The participants in this study represent essentially the same cross section of symptoms and, like the previous group, included a number who did not register any attentional deficits on the continuous performance tests administered. CPTs provide one of the few readily quantifiable measures in the field of behavior and psychology. They not only measure improvement in those subjects who were in deficit but also effectively track any degradation in attention and performance in those who did not measure as impaired upon initial assessment. This is a particularly important feature of any metric when exploring the efficacy of untried protocols --in this case, the use of the target frequencies in the infra-low frequency range (<0.1Hz). This domain expands the scope available for a neurofeedback strategy that has come to be referred to as frequency optimization, the tailoring of the target frequency to each individual. Frequency optimization is part of a neurofeedback protocol rationale developed by Susan Othmer at the EEG Institute (Othmer, 2010). It has been in use since the late nineties. Neurofeedback utilizing infra-low frequencies has been used at the EEG Institute since 2006. This approach has been taught to thousands of clinicians since that time. The strategy is an extension of earlier protocol approaches involving the use of inter and intra-hemispheric bipolar protocols (Othmer, 2005). Much of the increased flexibility in protocol selection is, of course, directly related to advances in the field of digital signal processing.

The existence of infra-low frequencies (or, equivalently, infra-slow oscillations) in the brain has been known for many years but their relevance to the EEG has only recently begun to be understood. Infra-low frequencies (ILF) are defined as those below 0.1 Hz. Although their origin is not completely clear, evidence suggests that they play a fundamental role in the management of cortical dynamics. The phase of the dominant frequency in upper ILF range has a direct relationship with spectral amplitudes in the conventional EEG band, reflecting modulations in cortical excitability (Monto, S. et. al., 2008). These low frequency oscillations also play a role in attention, where lower amplitudes of infra-slow activity are correlated with attention deficits (Helps, S. et. al., 2007). In addition, shifts in slow cortical potentials may also precede the onset of seizures (O.Leary and Goldring, 2007). In 2006, nearly half of the client population at the EEG Institute was training below 0.05 Hz (Othmer and Othmer, 2006). By the end of 2008, 77 % of the clients were training optimally at 0.001 Hz. By 2010, 0.1 mHz (0.0001 Hz) was being used by the majority of trainees as an optimal training frequency. The downward trend in target frequency was simply the result of tracking the optimum reward frequency for each individual, which gradually led to the exploration of ever lower frequency ranges as developments in signal processing made that possible. This makes the training a very different experience from what prevailed at the higher frequencies. In the mid-range of the EEG band (i.e., alpha and low beta frequencies) the visual system is unable to track the actual dynamics of the filtered signal. Instead the training signal is a derived value, namely the amplitude envelope of the selected signal. This yields a more slowly fluctuating function that the brain is able to track. This also yields a signal that is more directly relevant to the parameter being trained, namely cortical excitability. In the infra low frequency region the problem is very different. Here we are typically confronted with very long periodicities at the target frequency. An entire training session lasts only a fraction of a single cycle at the relevant frequency. Training on the amplitude envelope is out of the question. Instead one trains on the signal itself, and it is apparent that the brain finds this signal to be of great interest. This is surprising, because the signal seems relatively featureless in its slow migration. In fact, it reflects cortical activation directly in its more subtle fluctuations, and these must be what holds the brain's attentions (Othmer, 2015).

CPT measures are age-dependent, which calls for age-segmented norms. They are also somewhat time-of-day dependent, and also state dependent. Within those constraints, they offer reliable results that are sensitive to increments or decrements in performance over time that are uncompromised by practice effects. (More specifically, any practice effects quickly saturate during a brief practice period.) CPTs offer a useful measure of inattention and of impulse control in a wide range of psychiatric, neurological and educational impairments (J.M. Halperin, et.al. 1991). CPTs have also been used in determining effectiveness of medications on schizophrenics (E. Earle –Boyer, et.al., 1991). Previously, CPT advocates over-reached when touting the test as a means of diagnosing ADHD. The term diagnosis implies the imposition of a decision threshold. Thus the door for type 1 and 2 errors opens wide--leading to criticism and even disparagement. On the other hand, when using the test as a measure of degrees of impairment, in the multi-parameter space of a CPT, such criticism can usually be side-stepped. Despite the criticisms, CPTs are the most commonly used method for demonstrating the effectiveness of psycho-stimulants -–the most universally recommended intervention for ADHD. Of the psycho-stimulants, Methylphenidate (MPH) is the most thoroughly studied. Of the MPH studies, the majority indicated improvement on some aspect of CPT performance. Only five studies indicated no significant improvement (C.A. Riccio, et.al. 2001). Results of studies using CPTs and psycho-stimulants are generally positive and suggest that stimulant use often results in improvement in attention; reductions in reaction time and decreased variability. In addition, research suggests that higher doses of stimulant medication are associated with improved performance only up to optimal levels, beyond which performance declines (Rapport M. 2001). The ubiquitous use of CPTs in measuring the effectiveness of stimulant medications in the treatment of attention deficit disorders indicates that hey are considered a valid metric by the medical profession as a whole.

METHOD

Neurofeedback Protocols:

During the time period covered by these reports, the neurofeedback protocols were in a state of considerable flux. Placements were fairly consistent throughout, however, and nearly always utilized bipolar montage (2-site, 1-channel differential training). The rationale for initial site selection broke down in the following fashion: T3-T4 became the default placement for brain instabilities, mood instabilities and general physiological regulation problems. T4-P4 was the starting site for arousal regulation issues. The pre-frontal frontal sites (Fp1-T3, Fp2-T4, Fp1-Fp2) are included when there are problems with executive function, impulse control, emotional regulation, and obsessive- compulsive symptoms. The parietal sites are for addressing physical agitation, body dysmorphias, proprioception and kinesthetic awareness (P3-T3, P4-T4). The frontal areas (F3-T3, F4-T4) are included when addressing depression and motivation issues.

The principal variable to be managed by the clinician, in addition to choice of electrode placement, was the target frequency. Optimization of the target frequency was utilized throughout, but prior to 2008 the starting frequency for the optimization procedure was 12-15 Hz. Because of the substantial preference for the low reward frequencies, in 2008 the starting frequency was moved to 1.5 Hz for the instability protocol of T3-T4, and to 0.1Hz for the arousal stabilization protocol of T4-P4. In 2010 the starting target frequency was moved to 0.1mHz for all placements (Othmer, 2010). Once this new range was made available, the vast majority of trainees optimized their training within the vicinity of 0.1mHz. When the optimum response frequency (ORF) fell into the conventional EEG frequency region, the net signal was highly dynamic and was dominated as much by the relative phase at the two sites as by the amplitudes prevailing there. This was the topic of the prior paper (Putman et al, 2005). Matters are very different in the infra-low frequency region because the fundamental periodicity is larger than the timescale of the training. Both the signal amplitude at the two sites, and the phase relationship between them, change very slowly over the time course of a session. Additionally, we know that in this low frequency region the signals at the two training sites are highly correlated, which means they have a substantially common phase. They are close to being phase-locked. So not only is any phase change taking place slowly, but there isn't much taking place at all! Instead the brain is now locking onto fluctuations in the real-time signal, which is largely a matter of the relative amplitude between the two sites, reflecting differential cortical activation.

All electrodes were placed at the traditional sites according to the standard 10/20 placement system. Some variations in placement site occurred –such as placement slightly anterior or posterior to the temporal site location (T3,T4). Narrow-band filtering was used to select the frequency of interest, in considerable contrast to the 3-Hz bandwidth utilized in the conventional EEG band. On the other hand, narrow-band means something very different in the low-frequency region than at higher frequencies. Accompanying this reward scheme is an inhibit protocol that targets transient excursions into disregulation. A wide-band (variations on 0-40 Hz) inhibit scheme was used to suppress transient activity that stands out substantially above the ambient background levels of the EEG trace. The 40-Hz bandpass was segregated into ten sub-bands, and each of these was independently thresholded. Dynamically adjusted thresholds were used to accommodate secular trends in band amplitudes throughout the session. The training strategy underwent considerable modification over the years covered by this report. When the training focused on the standard EEG band with conventional threshold-based training, the reward criteria were generous, being typically set at or above 85%. Inhibitory thresholds were set at 10% typically, unless there were obvious reasons to do otherwise. The primary purpose of the inhibition scheme was to prevent the inadvertent rewarding of transient epileptiform, paroxysmal , or simply highly dysregulated activity that was signaled by an amplitude well in excess of the normal EEG trace for the particular band. Since the inhibit threshold was relatively high, this presented no conflict with a reward frequency that happened to be in the same band. The reward was continuous; the inhibits were merely episodic. The general approach with regard to the assignment of reward frequencies was to correlate them with the arousal level of the individual. In this regard, it is useful to think of high arousal states as emergency mode (fight or flight) states. High arousal is often associated with mental and physical agitation. There is difficulty calming and a tendency to react aggressively when stressed or threatened. Such states, when prolonged, can lead to exhaustion and drug (stimulant) seeking behaviors. Low arousal often manifests as difficulty maintaining alertness and normal responsiveness. Such individuals tend to be hypersensitive and will retreat or withdraw when under stress. Continuous performance tests (in this case the TOVA and the QIK), provide clues about arousal level. The low demand portion of the test (sparse target condition) will tend to push inattentiveness into prominence. Low arousal individuals tend to struggle during this portion of the test. On the other hand, the high demand portion (target-frequent condition) will tend to expose the individual with high arousal tendency to be impulsive and over-reactive (S. F. Othmer, 2010). Thus the low arousal ADD subtype will tend to have more omission errors on the CPT while the high arousal subtype will present with an excess of commission errors. With the entry into the infra-low frequency regime, this partitioning in to high and low arousal subtypes was no longer clinically relevant. That is to say, it did not have protocol implications. Every individual had a particular optimal frequency for the training, irrespective of their native tendencies on the arousal spectrum.

Measures:

There were two CPTs used in this study. The TOVA and the QIK test. The TOVA involves a brief (100 millisecond) visual presentation of one of two patterns every 2 seconds. One pattern is designated the ”target” and the other as the “non-target”. The distinction between the two patterns involves up-down discrimination. The person is instructed to press a micro switch when presented with the target and refrain from pressing on the non-target. The test duration is 22.5 minutes. The purpose of the TOVA is to assess sustained attention via impulse control, reaction time, variability of reaction time omission errors and commission errors (Leark, et.al 2007). The QIK test is identical to the TOVA in all respects except the following: It is a hand held device that requires recognition of lateral distinctions in the target object. In addition, unlike the TOVA, the response time cutoff is 150 ms instead of 200ms. In the original design of the TOVA, such fast responses were considered anticipatory. In some of the older data the 200 ms cut off may have skewed the data negatively since some of the best results were rejected as anticipatory (Leark et al., 2007). Due to the similarity in design of the two CPTs, the TOVA database was deemed suitable for use as the normative reference in the QIK test reports.

In this population, CPTs were administered prior to neurofeedback training and again after the first 20 sessions. Many factors can elicit transient attention deficits. These include sleep deprivation, situational stressors, diurnal effects and low blood sugar. In order to minimize diurnal effects, evaluations were done between 9 am and 2 pm whenever possible. Training periods were generally 30 minutes long. Training frequency varied from 2 to 10 sessions per week. There were few medication changes during the training. Typically, there are none during the first 20 sessions. Medications changes, if any, generally occur after there is tangible evidence that a change is warranted. It is therefore somewhat unusual for any changes to take place prior to the first re-evaluation. Subjects were asked to refrain from using any fast acting short duration stimulants prior to the evaluations.

Instrumentation:

Three neurofeedback systems were used in this study: The NeuroCybernetics system, the BioExplorer software, and the Cygnet–NeuroAmp system from bee Medic. The NeuroCybernetics system uses infinite impulse response (IIR) digital filtering with elliptic filters with analog signal gain set at 10,000 with digital conversion at 10-bit resolution. Instrument input impedance for each channel was set to one million megohms. Sampling rate was set at 160 per second. The Bio-Explorer unit was utilized for the initial exploration of the infra-low frequency region, as it provided for filter bandwidths extending down to 0.1 Hz center frequency.

The Cygnet-Neuro Amp system has a base sampling rate of 1000 per second, with down-sampling to 250 Hz. Bessel filters of second order are used for inhibits and rewards. Digital resolution in this dc-coupled design is greater than 24 bits.

In each system, the raw signal trace was displayed in a continuous horizontal scrolling or swept fashion for monitoring by the technician. Upon digital filtering, the signal was sent to a second computer where it was mapped into different features of a video game for viewing by the participant. Changes in the targeted aspects of the signal (rewarded and inhibited frequencies) were registered in visual, auditory and tactile feedback.

Statistics:

Analysis of variance was performed on all 4 scales of the continuous performance test. An additional analysis was done on the same scales but excluding all of those whose initial CPT scores were over 100. Since we were confined to 2 groups of data (a single group of subjects with repeated measures), analyses of variance ANOVA for paired samples was used to compare the validity of the pre- and post-NF training means. ANOVA measures can be derived via the specific t values where $F = t^2$. The Bonferroni correction was used to reduce the possibility of Type I errors. Even the strictest alpha value (.01) would have allowed for a per scale value of $p = .0025$ -far greater than the actual p values achieved. Even by the most conservative standards the training yielded highly significant results.

RESULTS (through March 2010)

Below is a breakdown of the standard scores for each of the 4 scales based on standard deviation and ranked in order of severity of impairment -prior to the neurofeedback training (N= 249). The pre-training scores are in blue and the post training scores are in red.

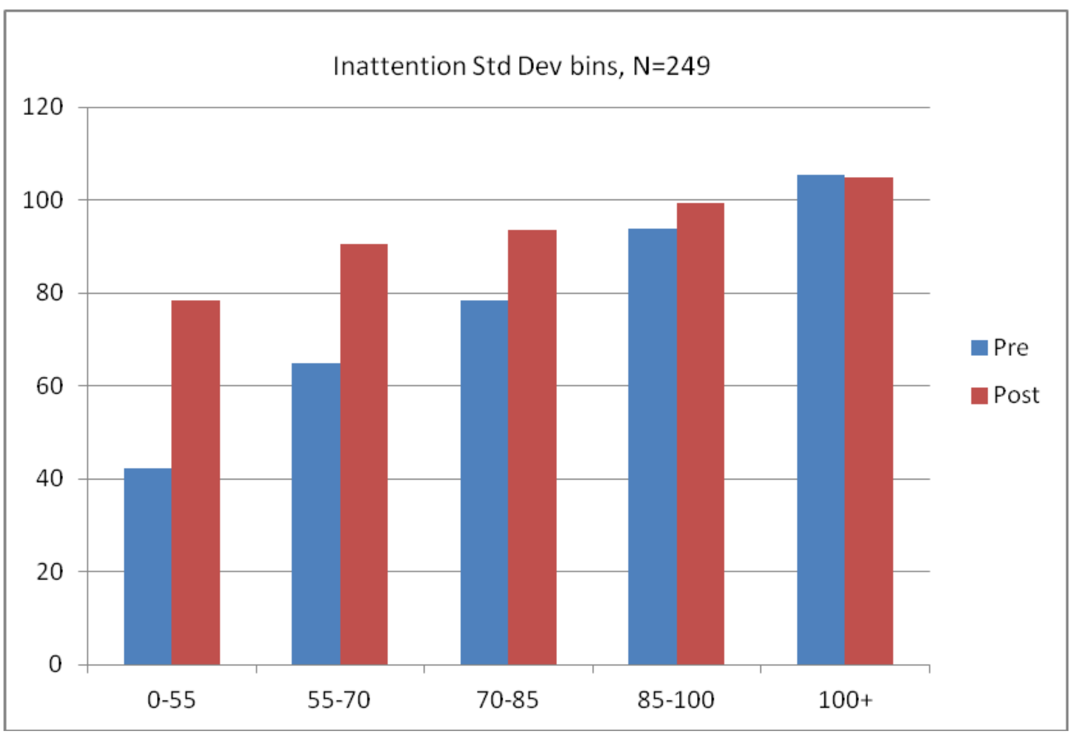

Figure 1

Om., 0-55	Mn	N	Std Dev	F(1,N-1)	Sig.
(249) Pre	42.34	52	4.25	82.8	P< .001
Post	78.33		27.9		

Om., 55-70	Mn	N	Std Dev	F(1,N-1)	Sig.
Pre	64.8	10	3.97	22.5	P=.001
Post	90.6		17.05		

Om. 70-85	Mn	N	Std Dev	F(1,N-1)	Sig.
Pre	78.3	30	4.67	38.4	P<.001
Post	93.53		13.55		

Om., 85-100	Mn	N	Std Dev	F(1,N-1)	Sig.
Pre	93.8	50	4.7	14.4	P<.001
Post	99.36		9.4		

Om., 100+	Mn	N	Std Dev	F(1,N-1)	Sig.
Pre	105.55	107	2.95	0.45	P=.505
Post	104.88		10.67		

Table 1

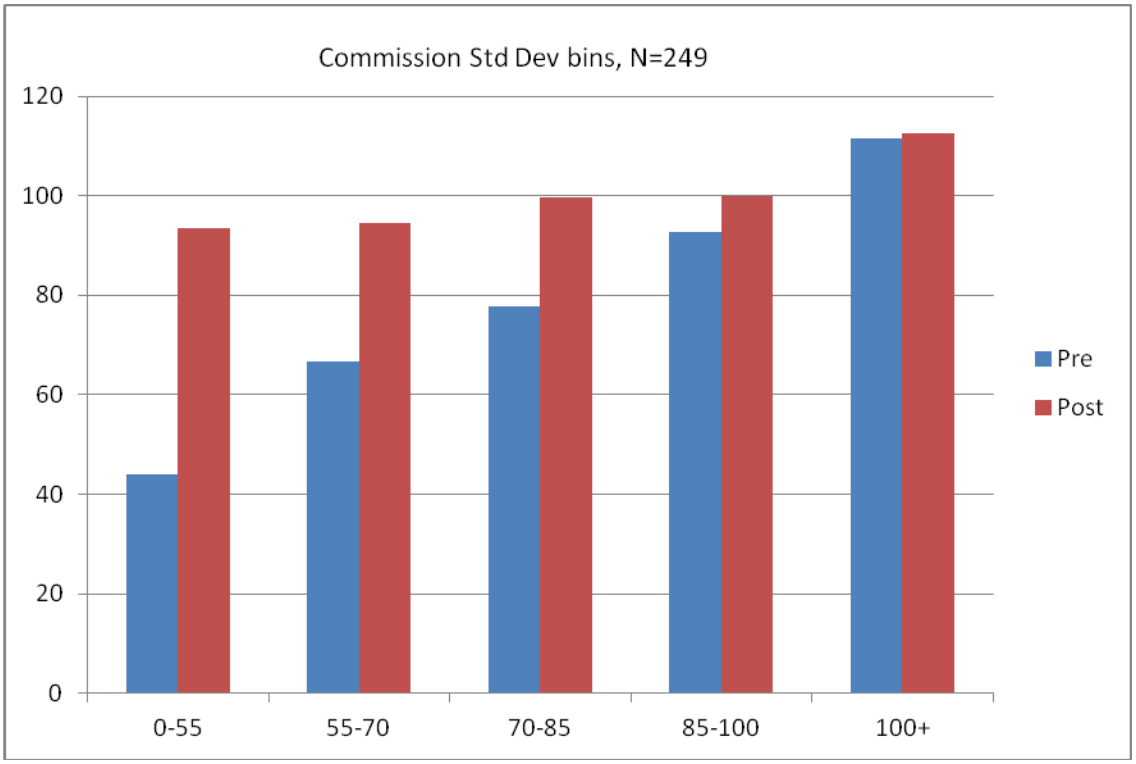

Figure 2

Com., 0-55	Mn	N	Std Dev	F(1,N-1)	Sig.
(249)Pre	43.95	22	5.15	94	P<.001
Post	93.64		22.46		

Com., 55-70	Mn	N	Std Dev	F(1,N-1)	Sig.
Pre	66.82	11	2.86	51.8	P<.001
Post	94.45		13.66		

Com., 70-85	Mn	N	Std Dev	F(1,N-1)	Sig.
Pre	77.67	24	4.99	79.2	P<.001
Post	99.67		13.07		

Com., 85-100	Mn	N	Std Dev	F(1,N-1)	Sig.
Pre	92.67	68	4.7	21.2	P<.001
Post	99.87		13.31		

Com., 100+	Mn	N	Std Dev	F(1,N-1)	Sig.
Pre	111.56	124	5.96	0.94	P=.333
Post	112.64		11.66		

Table 2

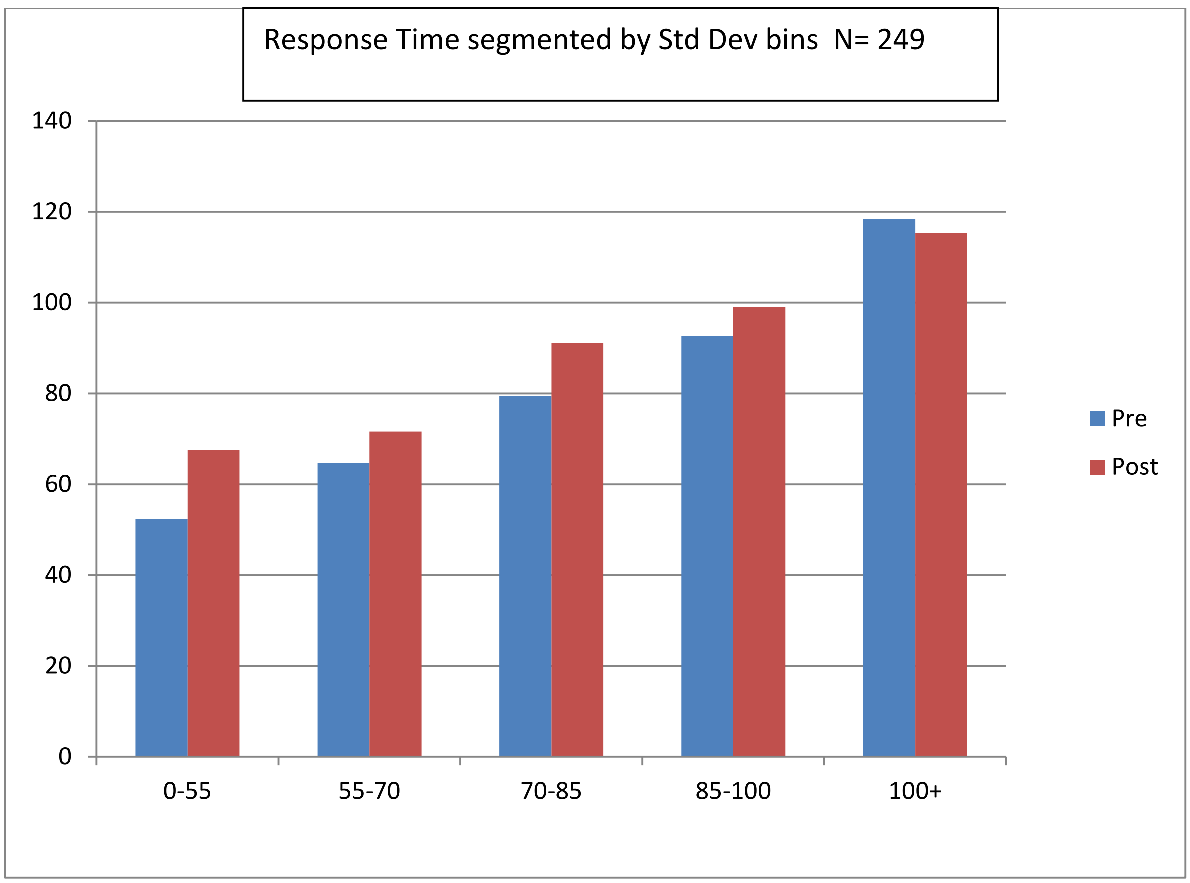

Figure 3

RT: N=249	Mn	N	Std Dev	F(1,N-1)	Sig

Pre 0-55	52.4	18	21.3	11.9	P= .004
Post	67.5		22.9		

	Mn	N	Std Dev	F(1,N-1)	Sig
Pre 55-70	64.7	21	4.98	8.2	P= .01
Post	71.6		19.73		

	Mn	N	Std Dev	F(1,N-1)	Sig
Pre 70-85	79.4	33	4.47	15.2	P< .001
Post	91.1		16.28		

	Mn	N	Std Dev	F(1,N-1)	Sig
Pre 85-100	92.7	50	4.36	8.8	P= .005
Post	99.0		16.21		

	Mn	N	Std Dev	F(1,N-1)	Sig
Pre 100+	118.5	127	14.0	8.1	P=.005
Post	115.4		15.76		

Table 3

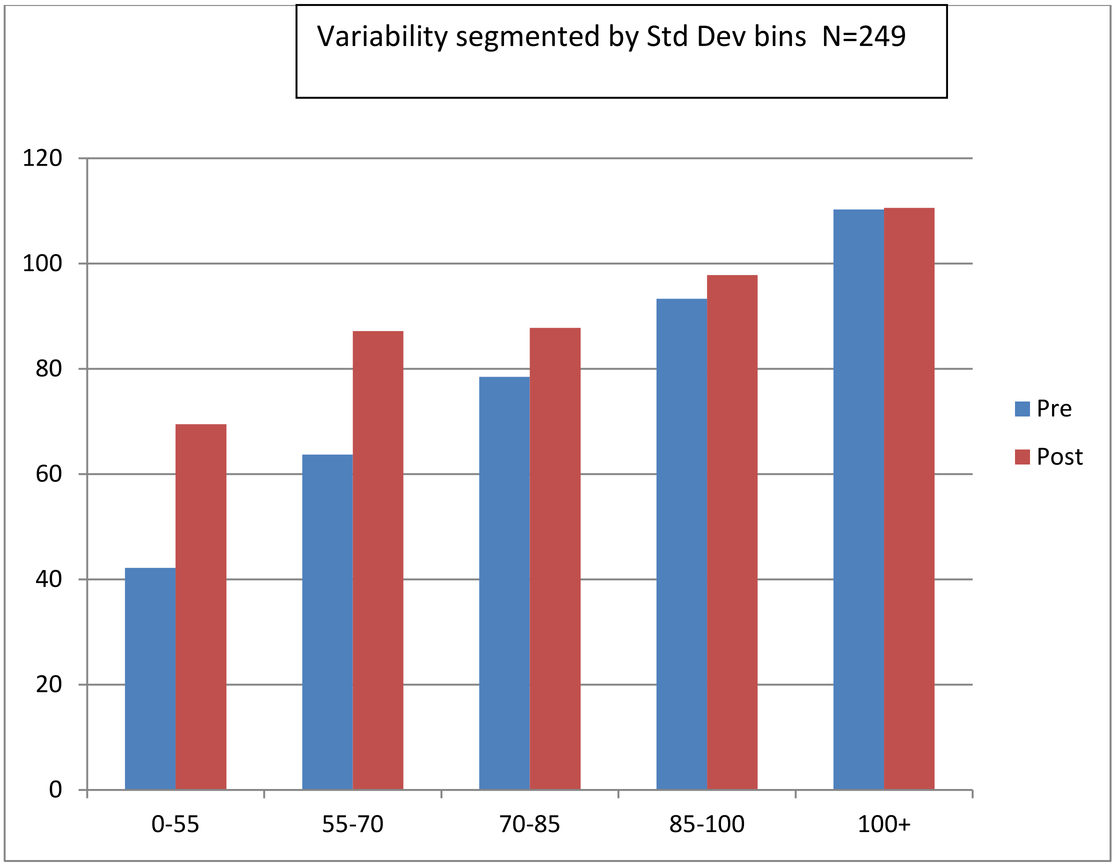

Figure 4

Var: N=249	Mn	N	Std Dev	F(1,N-1)	Sig
Pre 0-55	42.2	38	4.36	38.5	P<.001
Post	69.5		26.54		

	Mn	N	Std Dev	F(1,N-1)	Sig
Pre 55-70	63.7	27	4.39	47.6	P<.001
Post	87.2		18.05		

	Mn	N	Std Dev	F(1,N-1)	Sig
Pre 70-85	78.5	49	4.44	14.7	P<.001
Post	87.8		17.7		

	Mn	N	Std Dev	F(1,N-1)	Sig
Pre 85-100	93.3	67	4.57	4.5	P=.037
Post	97.8		17.6		

	Mn	N	Std Dev	F(1,N-1)	Sig
Pre 100+	110.3	68	7.19	3.8	P=.846
Post	110.6		12.86		

Table 4

Below is a list of pre- and post-standard scores by scale, for those of the 249 who scored below 100 on their initial CPT evaluation.

Omission, N=134, (pre-test< 100)

Mn pre	Mn post	STD pre	STD post	F (1, 133)	Sig.
67.81	89.37	22.19	21.75	113.42	P < .001

Table 1b

Commission, N=115 (pre test < 100)

Mn pre	Mn post	STD pre	STD post	F (1, 114)	Sig.
77.37	97.79	18.78	15.75	97.22	P < .001

Table 2b

Response Time, N=119 (pre-test < 100)

Mn pre	Mn post	STD pre	STD post	F (1, 118)	Sig.
77.59	88.08	16.78	21.30	42.25	P < .001

Table 3b

Variability, N= 174 (pre-test < 100)

Mn pre	Mn post	STD pre	STD post	F (1,173)	Sig.
73.04	86.91	19.49	22.33	69.39	P< .001

Table 4b

As has been the case with all previous examinations of the data, there was a clear trend towards normalization on all 4 individual scales of the CPT. This trend was even more evident when the standard scores were broken down by 15 point bins–each bin representing 1 standard deviation (Figures 1-4 and Tables 1-4). When eliminating those subjects who initially tested above a standard score of 100 on each scale, the results are even more dramatic (Tables 1b-4b). In addition, all those whose pre-training scores were above 100 were examined to see if there was any significant deterioration in performance. Omission, Commission and Variability scores yielded no significant changes at the 100+ pre-training level. Overall, those subjects exhibiting the greatest degree of impairment upon intake, showed the most improvement upon reexamination after the 20+ training sessions.

Combining the Scales

The Combined Scales measure involves taking the Mean of all 4 scales and comparing the pre-training Mn to the post training Mn. Doing so causes the outliers to get washed out by the averaging process. Although the value of this measure hasn't really been established with respect to its clinical implications, it does give us a "high altitude" reference point regarding the overall trending in brain function (with an increase in CS score reflecting a general improvement in functioning).

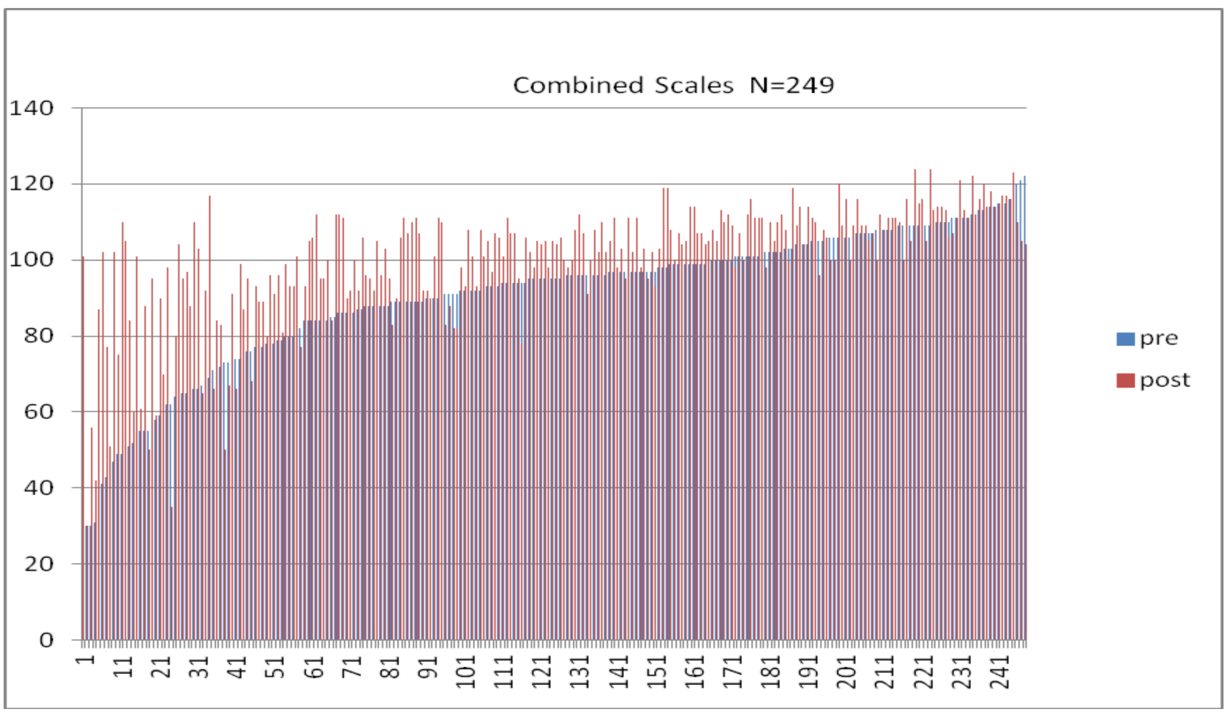

Figure 5 Combined Scales

Mn pre	Mn post	Std Dev pre	Std Dev post	F (1,248)	Sig
90.65	99.91	18.02	16.29	100.8	P< .001

Table 5

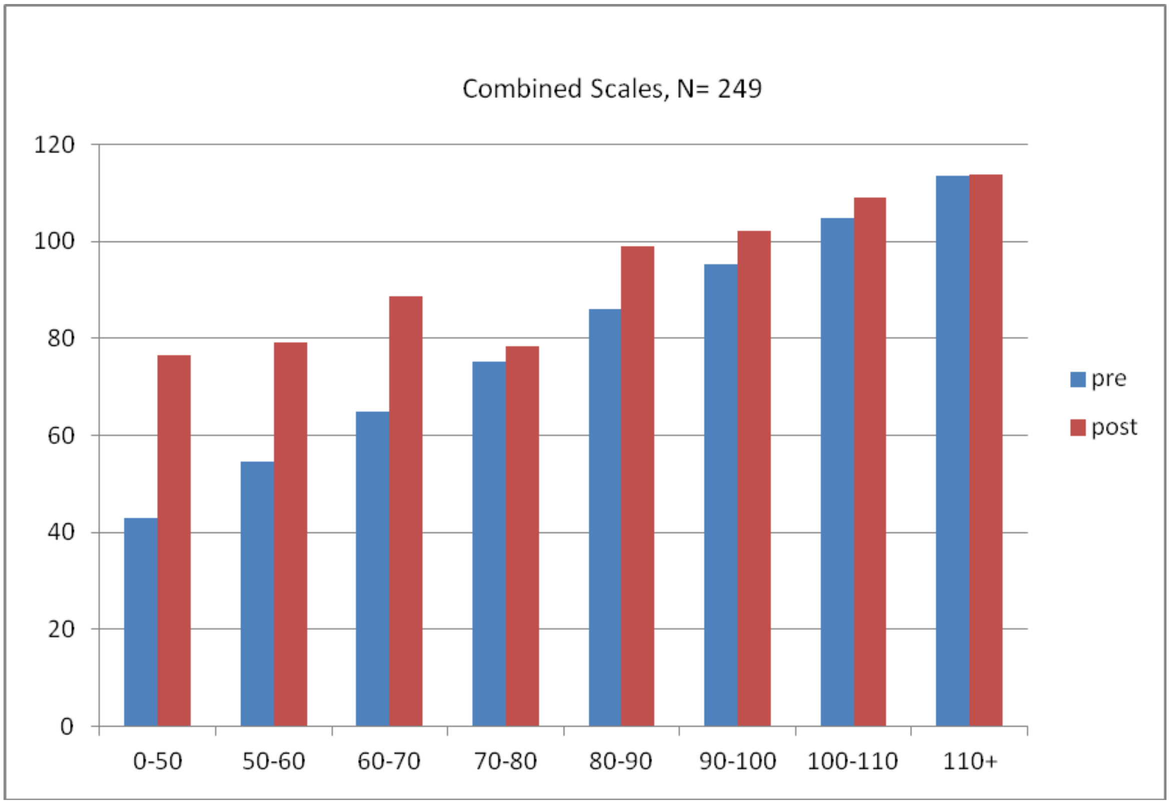

Figure 6

In Table 5, Figures 5 and 6, the average of all four scales for the entire sample of 249 was examined – pre to post. Fig. 5 shows the overall and Fig. 6 breaks down the results into 10 point bins -which parallels the trend towards normalization observed in each scale individually.

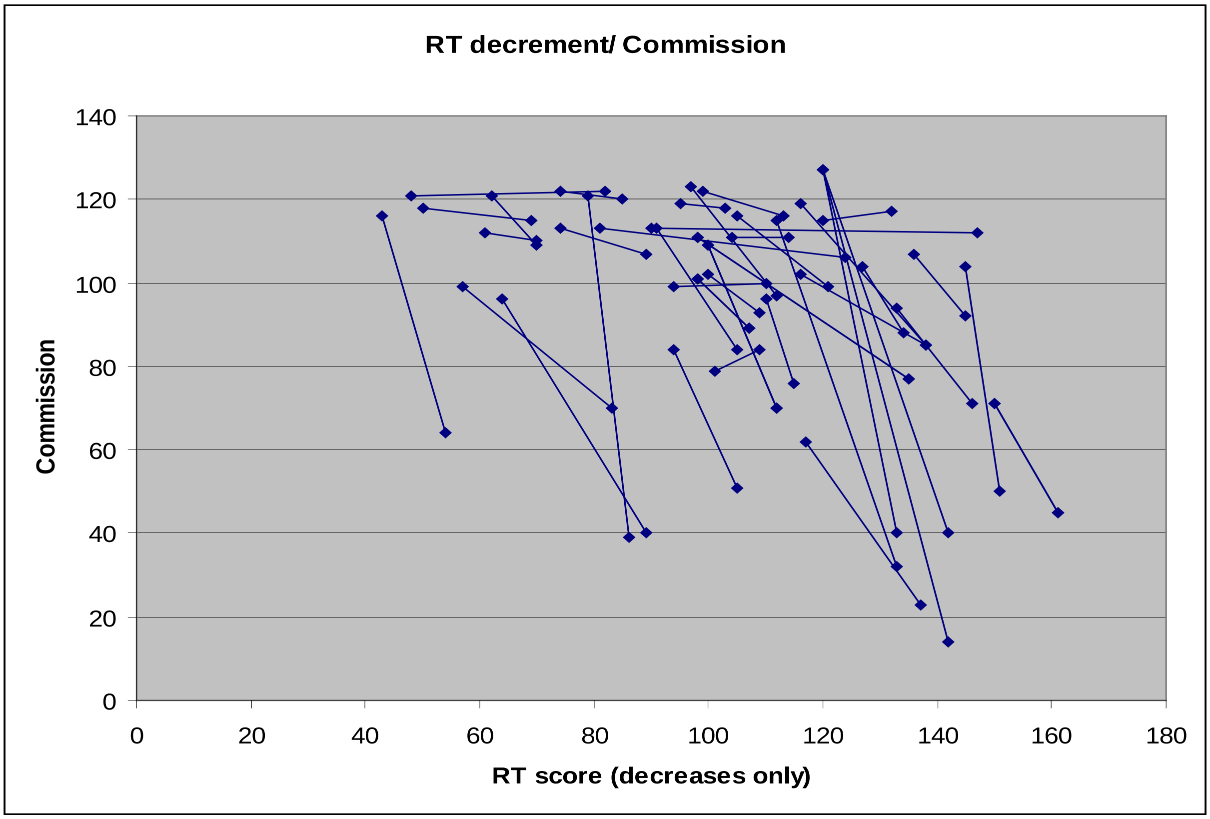

Figure 7

Interestingly, there was a significant increase in the response time in the normal (100+ pre-training score) individuals (Mn pre = 118.17, SD= 14.1, Mn post = 115.21, SD= 15.7, N= 130, F= 7.62, p = .007). This is because many of the inordinately high initial RT scores are associated with those subjects who fire blindly at "target" and "non-target" alike --i.e. suffer from poor impulse control. (Note that a Response Time score on the CPT in inversely related to the actual response time). Following the training, the response time moves to its proper level, reflective of events that took time to assess and respond accurately to the visual information. Typically, when RT scores decrease (indicating slower responses) we see an improvement on the commission scale (less impulsivity). Figure 7 compares the relationship between response time score and commission score in all of those subjects whose RT score decreased from pre-training to post. In other words, all the bars will move right to left over the RT scale. All subjects had to have a decrease of at least 5 points on the RT standard score to be included in this sample (N= 42). What is noteworthy is that nearly all decreases in RT are correlated with improvements in the commission score (the vertical scale). As usual, the worse the initial score, the more dramatic the improvement. Conversely, less impairment upon initial testing is correlated with smaller improvements. Commission saturation is indicated by all the bars approaching the horizontal above a standard score of 100 on the Commission scale. In sum, then, the apparent decrease in RT score is largely artifactual in that it reflects mostly the reduction in impulsive pure reaction time events in consequence of the training. It has become very clear over time that reduction in impulsivity does not have to be purchased at the cost of increased reaction time.

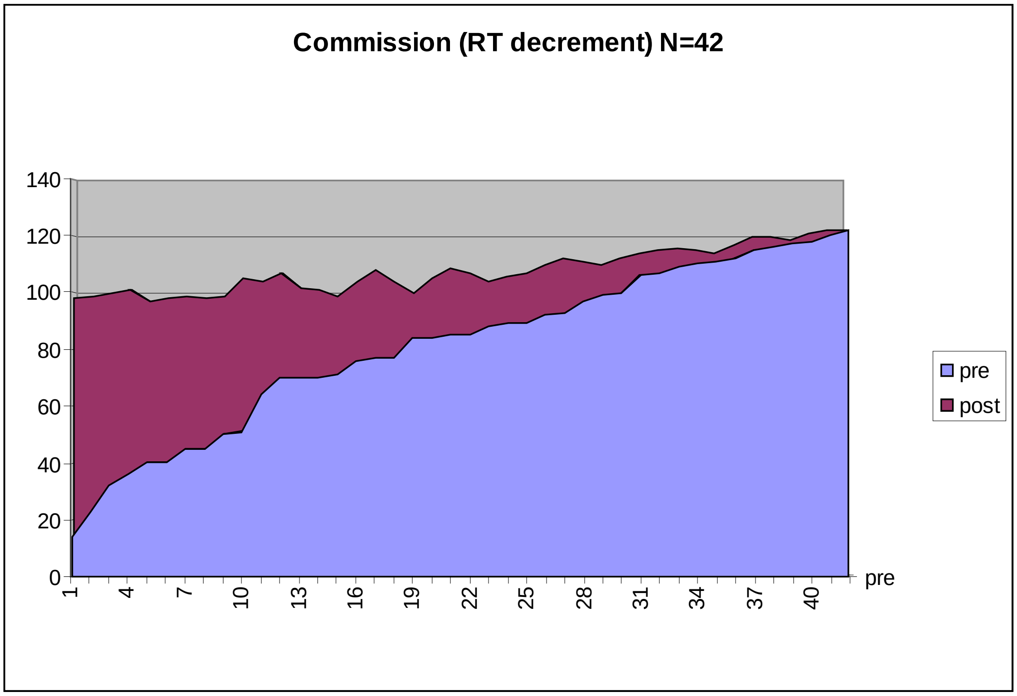

Figure 8

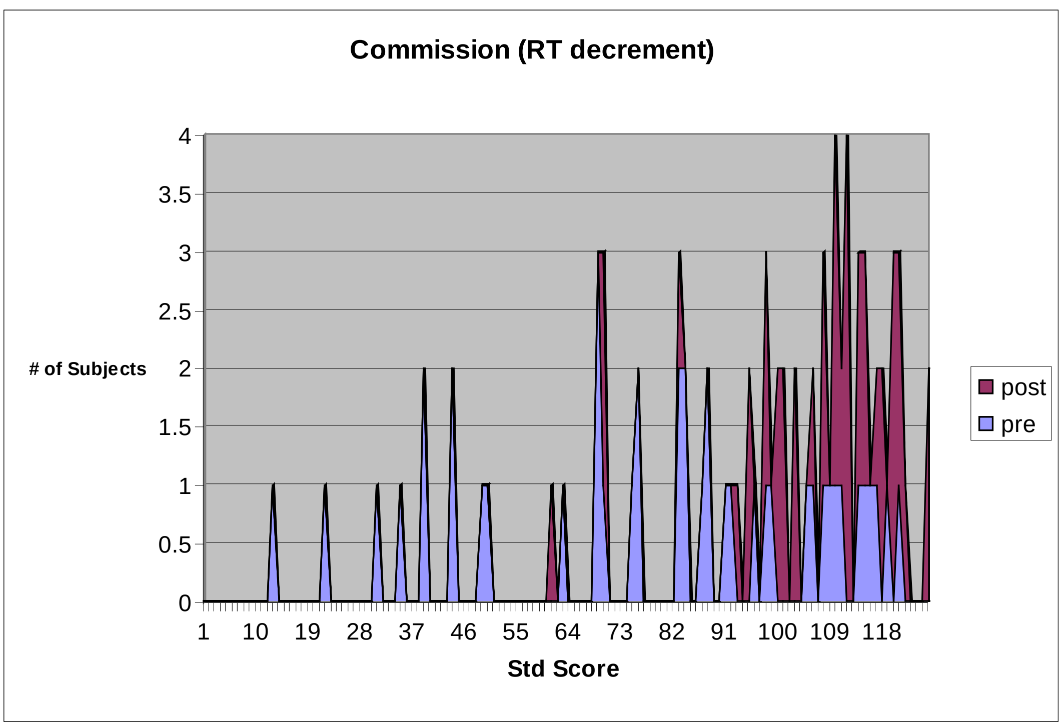

Figure 8b

Figure 8 represents the trend in the Commission scores for the same group of people and again shows the stark relationship between degrees of initial impairment and post training improvement. Figure 8b illustrates the commission score movement relative to the number of subjects as indexed by individual standard score bins (–i.e. the pre- and post-score distributions by number of subjects). It represents the same information in Figure 7 but is collapsed over the RT score axis.

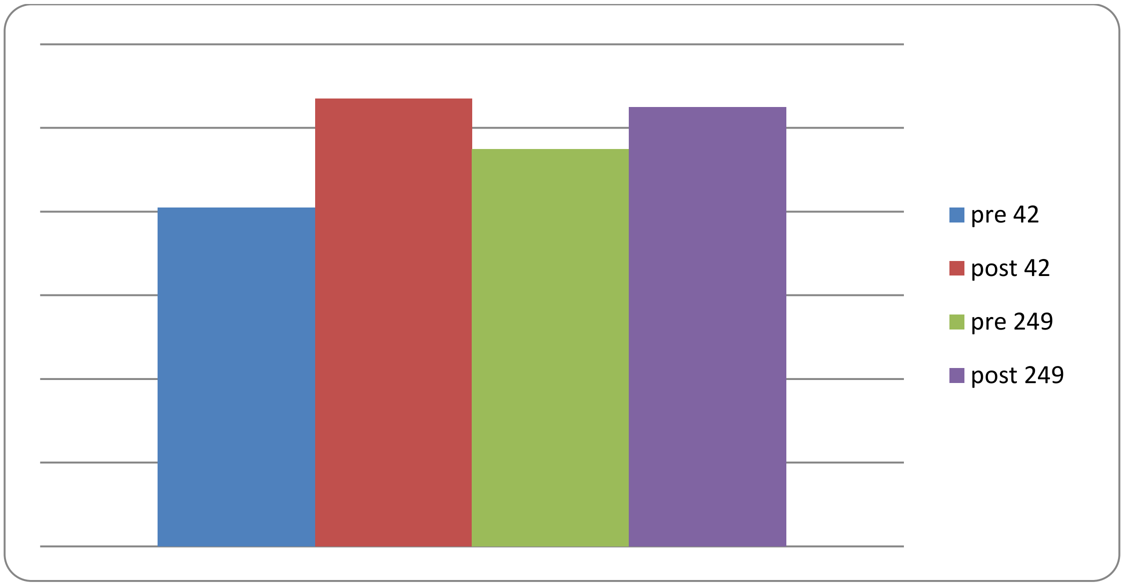

Figure 9

Figure 9 represents a comparison of the commission scores for the response time score decrement group (pre score= 81, post = 107, N=42) and the commission scores for the entire group (pre = 95, post = 105, N=249). It appears that those who slowed down showed greater improvement (1.73 std. dev.) when compared to the overall (.67 std. dev.) -–suggesting an increase in deliberate choice making.

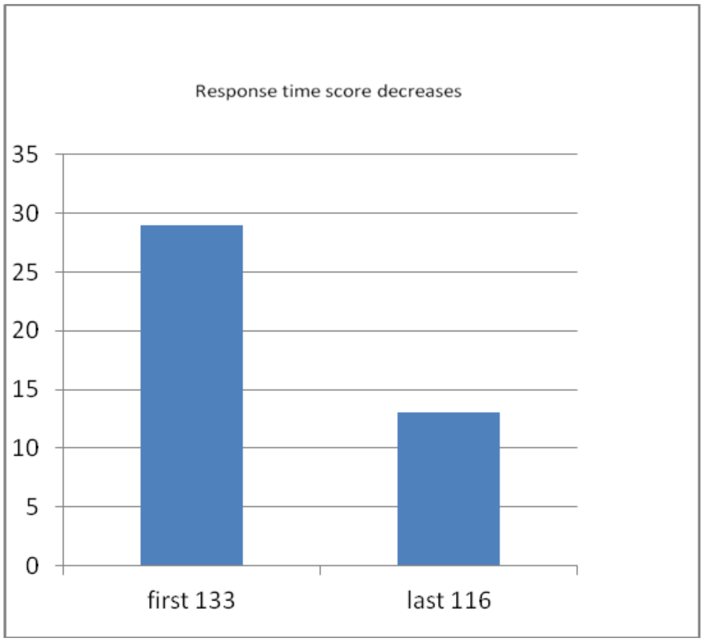

Figure 10

Also, it was noted that the majority of the RT regressions were in the first half of the data samples (29 out of an N=133 as of 2007). 13 were recorded in the most recent half of the data (N=116 from 2007 to 2010). This is illustrated in Figure 10. The incidence was essentially cut in half in the later data set. This suggests the existence of a second factor that helps to account for the data. For example, a shift in the client population to older age groups over this time frame could account for the reduction in incidence. Pure reaction time events are a particular issue in children of age six, seven, and eight. This hypothesis has not been pursued.

CPT Results (through August 2012)

Below is a breakdown of two groups: N=101 and N= 350. The first set represents the combined scales for the most recent 101 (-i.e. the exclusively infra-low-frequency trainees). The second set represents the entire group of 350 that includes multiple reward frequencies-–but nearly all from bipolar derivations. When looking at both groups in their entirety, we include a large number of persons who tested 'normal' on the pre-training QIK test. Doing so tends to moderate the overall results somewhat, but we still observe a significant improvement. However, when looking at the results as a function of the initial degrees of impairment, the statistical changes look more impressive. For each set, the first sub-grouping is for those whose pre-training combined score was < 85 (16^{th} percentile). The second is for those whose initial score was between 85 and 100. When comparing the pre- to post-means between the two sets of data (Tables 11 and 16), they are remarkably similar.

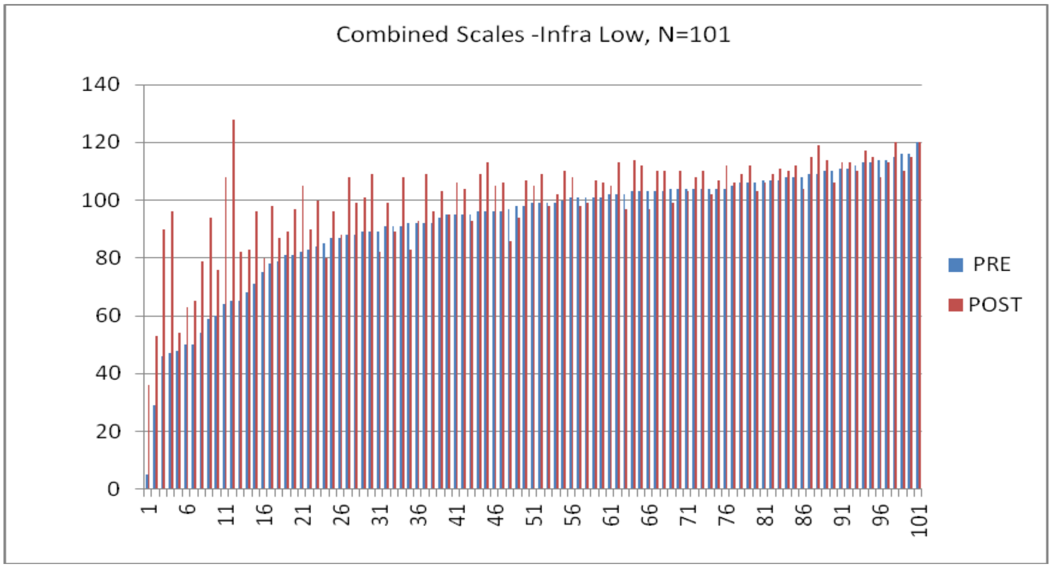

Fig.11

COMBINED SCALES TOTAL **N=101**

Combined-IL	Mean	N	Std Dev	F (1,101)	df	Sig.
Pre training	92.36	101	20.48	44.4	100	P< .001
Post	100.45	--	14.97	--	--	--

COMBINED SCALES **N= 101** (for pre scores < 85)

Combined 101	Mn	N	Std Dev	F (1,24)	df	Sig
Pre	62.67	24	20.21	44.9	23	P<.001
Post	84.29	--	19.84	--	--	--

COMBINED SCALES **N= 101** (for pre scores 85< and < 100)

Combined 101	Mn	N	Std Dev	F (1,101)	df	Sig
Pre	93.71	31	4.0	19.0	30	P<.001
Post	100.16	--	8.55	--	--	--

Table 11

Below are the individual pre- to post-scores for each scale for the entire group of 350.

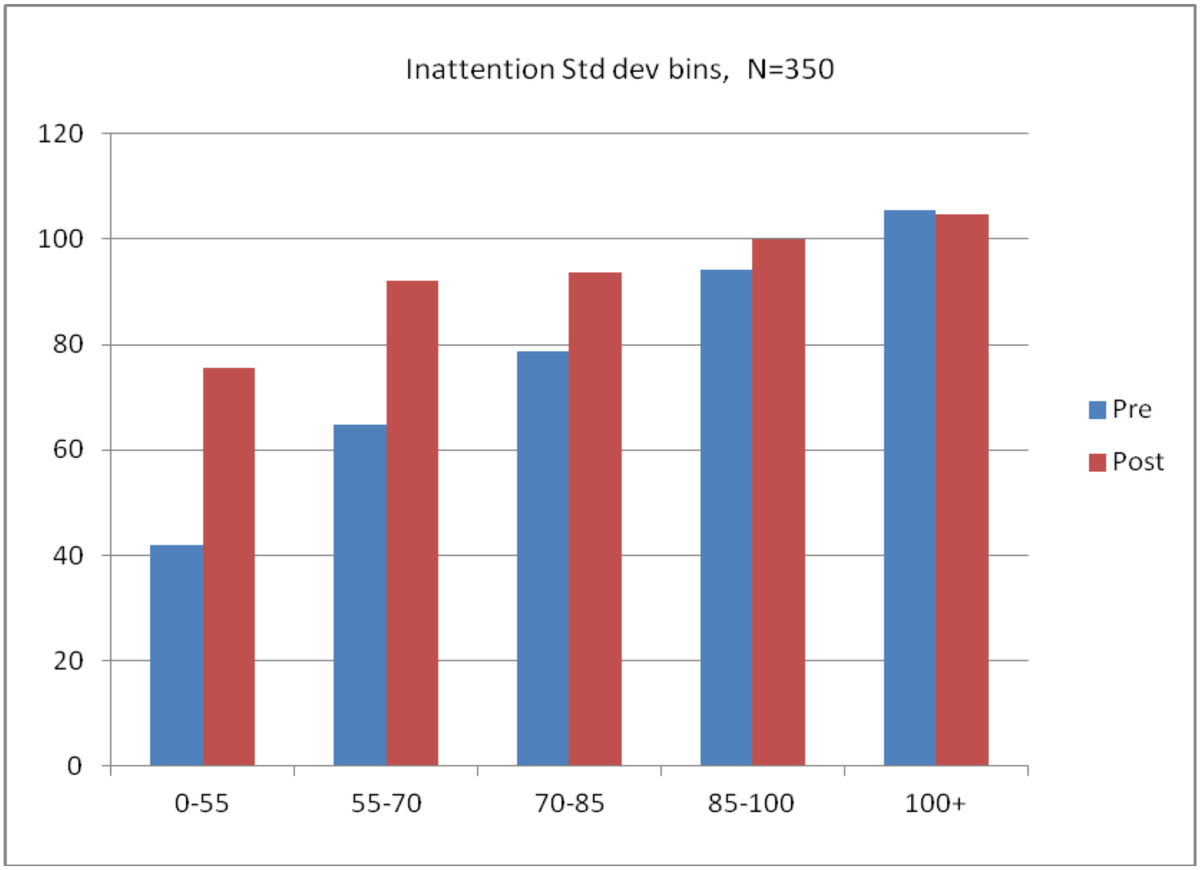

Fig. 12

Om., 0-55	Mn	N	Std Dev	F(1,N-1)	Sig.
(350)Pre	42.01	67	4.0	98.0	P<.001
Post	75.54		28.03		

Om., 55-70	Mn	N	Std Dev	F(1,N-1)	Sig.
Pre	64.9	11	3.78	25.0	P<.001
Post	92.0		16.82		

Om., 70-85	Mn	N	Std Dev	F(1,N-1)	Sig.
Pre	78.6	37	4.75	41.0	P<.001
Post	93.76		14.05		

Om., 85- 100	Mn	N	Std Dev	F(1,N-1)	Sig.
Pre	94.19	75	4.55	21.2	P<.001
Post	99.5		9.2		

Om., 100+	Mn	N	Std Dev	F(1,N-1)	Sig.
Pre	105.6	160	2.76	1.6	P = .214
Post	104.7		9.36		

Table 12

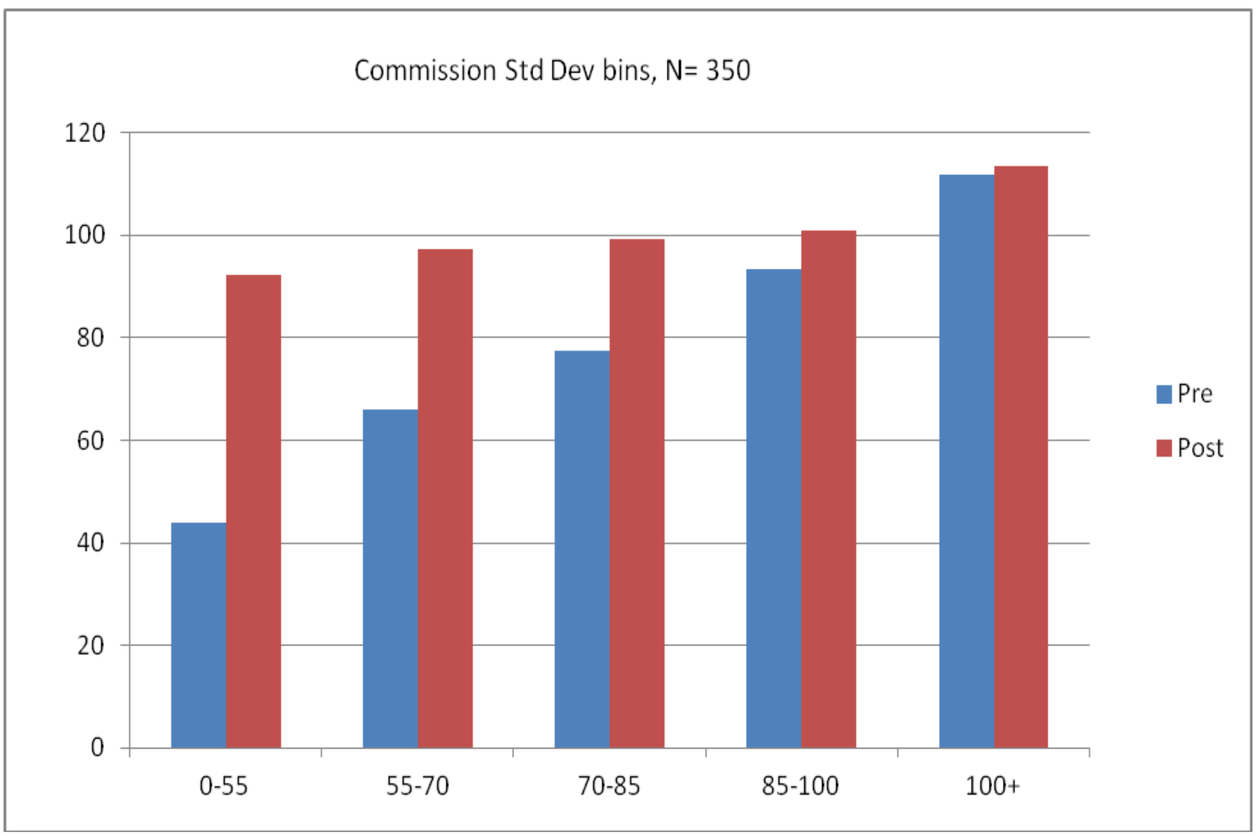

Fig. 13

Com, 0-55	Mn	N	Std Dev	F(1,N-1)	Sig.

(350)Pre	43.9	25	5.15	106	P<.001
Post	92.2		23.74		

Com., 55-70	Mn	N	Std Dev	F(1,N-1)	Sig.
Pre	66.61	13	2.72	57.8	P<.001
Post	97.31		14.85		

Com., 70-85	Mn	N	Std Dev	F(1,N-1)	Sig.
Pre	77.5	32	4.85	86.5	P<.001
Post	99.28		13.41		

Com., 85-100	Mn	N	Std Dev	F(1,N-1)	Sig.
Pre	93.53	79	4.87	30.2	P<.001
Post	100.90		12.84		

Com., 100+	Mn	N	Std Dev	F(1,N-1)	Sig.
Pre	111.94	201	6.04	3.6	P= .054
Post	113.36		10.15		

Table 13

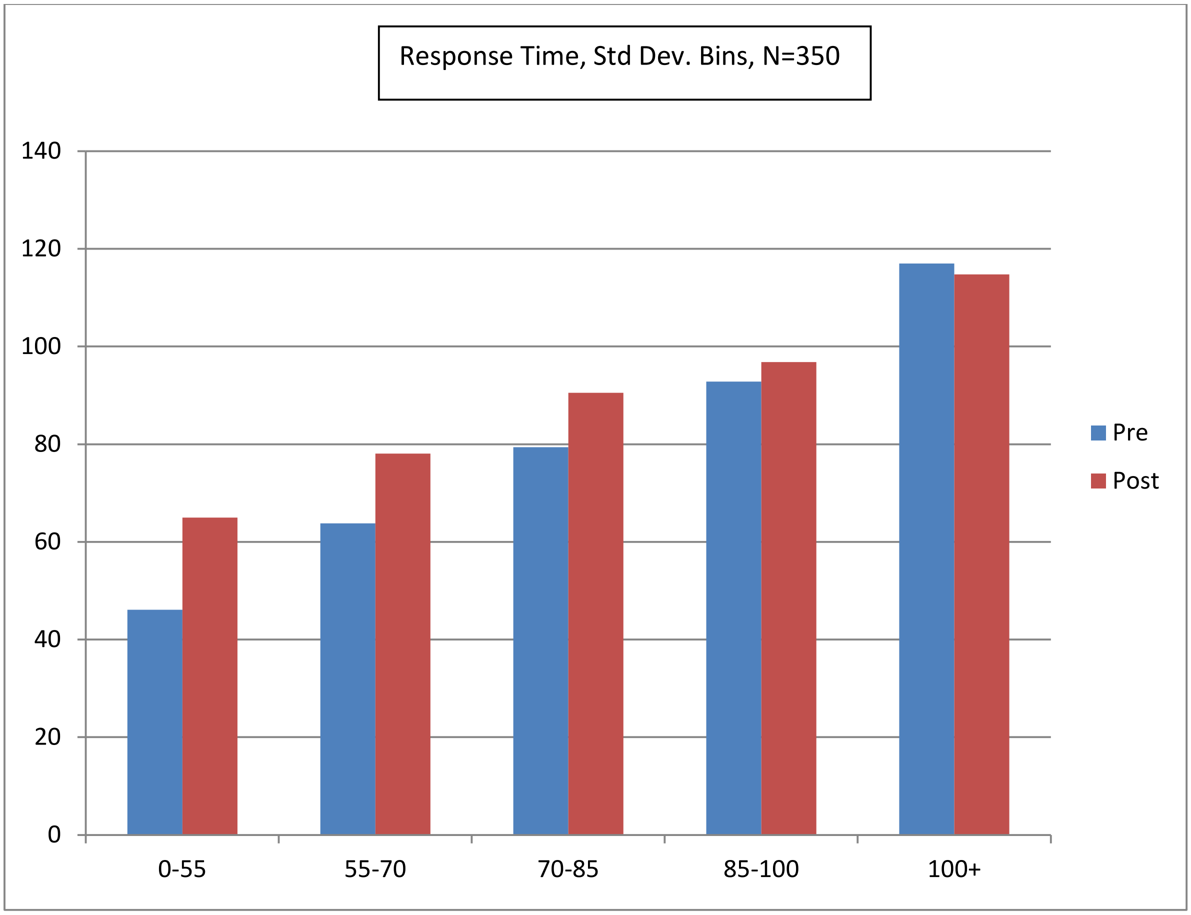

Fig. 14

RT: N=350	Mn	N	Std Dev	F(1,N-1)	Sig
Pre 0-55	46.1	21	5.75	22.1	P<.001
Post	64.9		19.75		

	Mn	N	Std Dev	F(1,N-1)	Sig
Pre 55-70	63.8	28	4.94	14.4	P=.001
Post	78.1		18.53		

	Mn	N	Std Dev	F(1,N-1)	Sig
Pre 70-85	79.4	49	41.67	24.6	P<.001
Post	90.5		15.61		

	Mn	N	Std Dev	F(1,N-1)	Sig
Pre 85-100	92.8	78	4.37	4.0	P=.046
Post	96.8		18.12		

	Mn	N	Std Dev	F(1,N-1)	Sig

Pre 100+	117.0	174	13.02	6.3	P=.013
Post	114.8		15.15		

Table 14

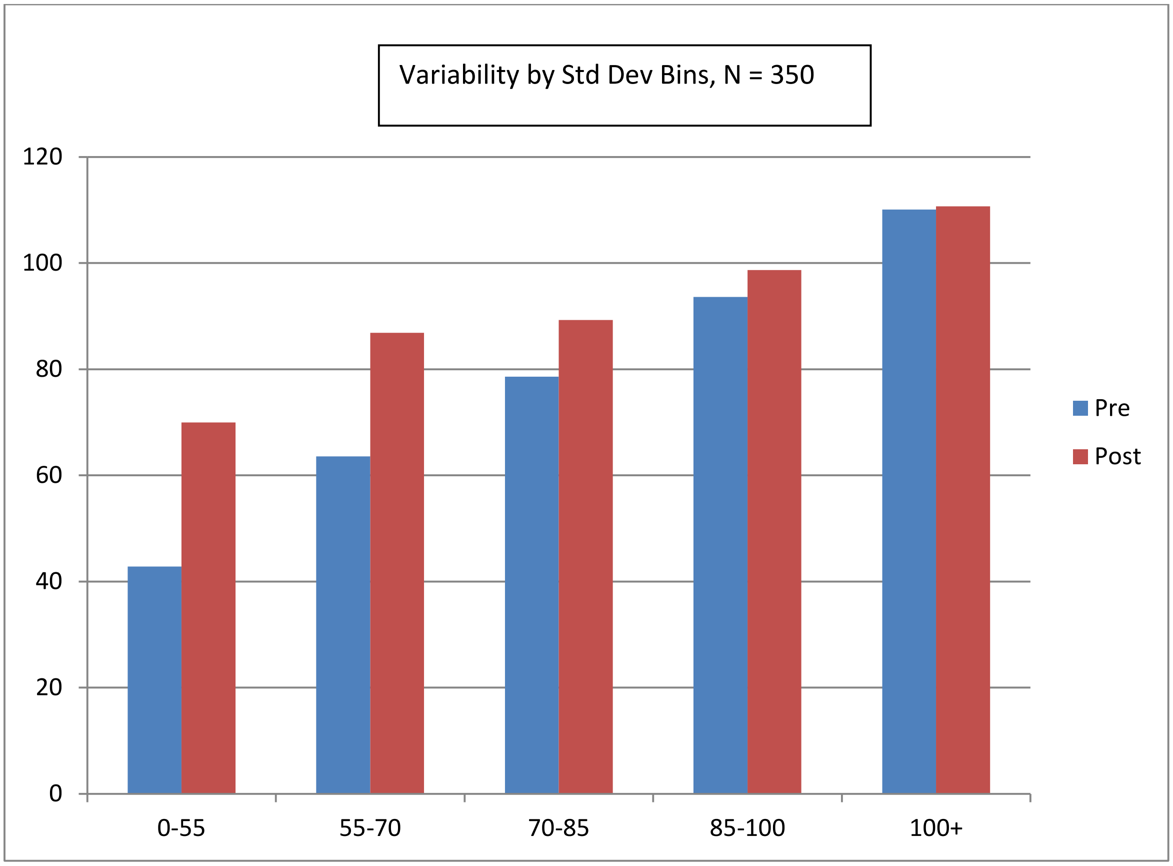

Fig. 15

Var: N=350	Mn	N	Std Dev	F(1,N-1)	Sig
Pre 0-55	42.8	57	4.61	68.6	P<.001
Post	70		24.63		

	Mn	N	Std Dev	F(1,N-1)	Sig
Pre 55-70	63.6	35	4.26	63.4	P<.001
Post	86.9		17.2		

	Mn	N	Std Dev	F(1,N-1)	Sig
Pre 70-85	78.6	65	4.44	22.1	P<.001
Post	89.3		18.59		

	Mn	N	Std Dev	F(1,N-1)	Sig

Pre 85-100	93.6	94	4.4	13.3	P=.003
Post	98.7		16.18		

	Mn	N	Std Dev	F(1,N-1)	Sig
Pre 100+	110.1	99	6.66	.27	P=.608
Post	110.7		11.68		

Table 15

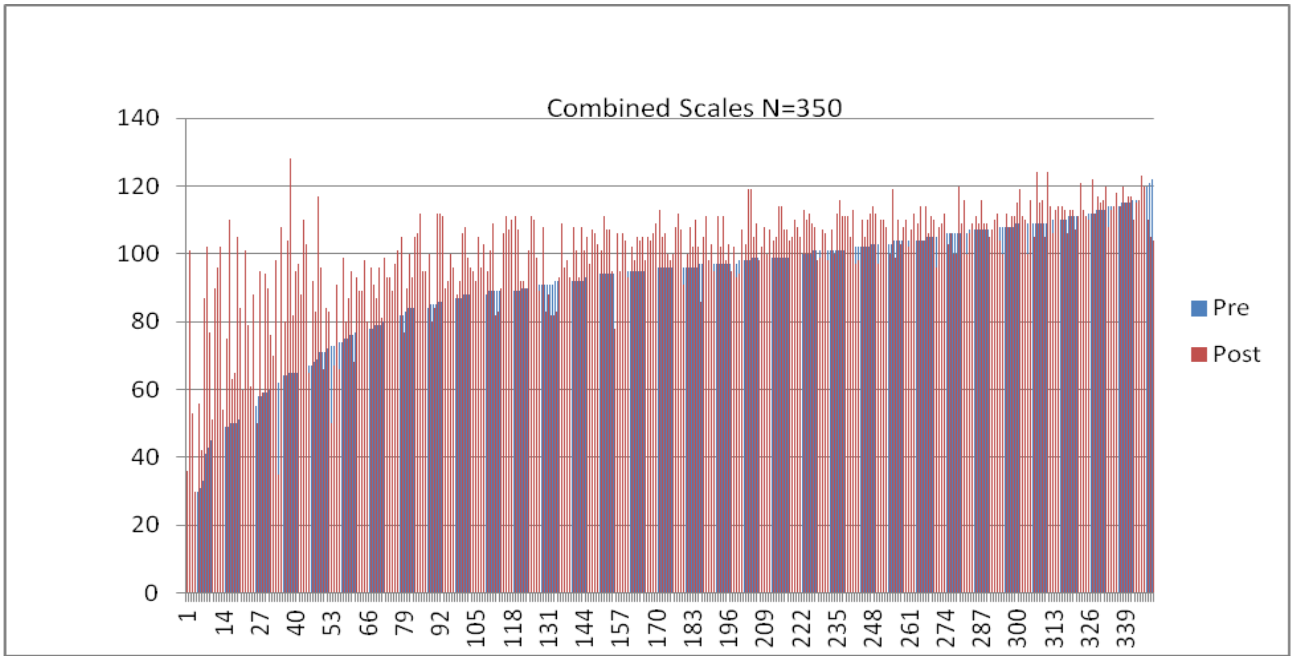

Fig. 16

COMBINED SCALES TOTAL **N=350**

Combined - Total	Mean	N	Std Dev	F (1,349)	df	significance
Pre training	91.15	350	19.16	143.3	349	P<.001
Post	100.07	--	16.01	--	--	--

COMBINED SCALES **N=350** (for pre scores $\leq$ 85)

Combined 350	Mn	N	Std Dev	F (1, 91)	df	Sig
Pre	64.94	91	16.9	75.69	90	P<.001
Post	84.16	--	21.04	--	--	--

COMBINED SCALES **N=350** (for pre scores 85< and ≤ 100)

Combined 350	Mn	N	Std Dev	F (1, 133)	df	Sig
Pre	93.7	133	4.04	131.1	132	P<.001
Post	101.56	--	8.24	--	--	--

Table 16

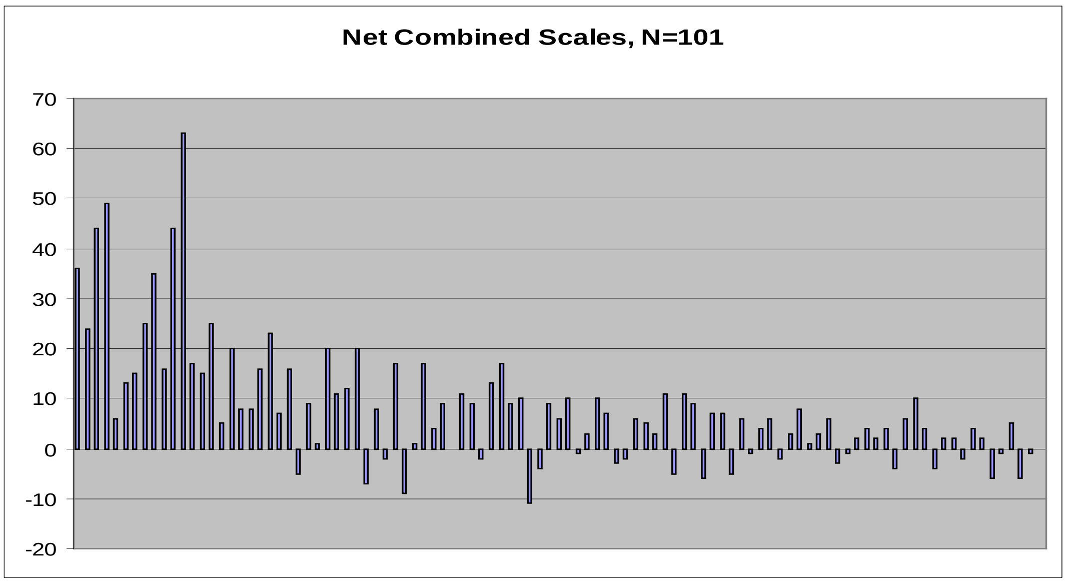

Figure 17 Combined scale score –Net changes (N=101)

Combining the 4 scales (pre- and post-NF mean for the QIK test) tends to smooth out the data and reveals the overall trend of movement with regard to the CPT. Figure 17 represents the combined scales score for the most recent 101 records. These records represent those persons who underwent exclusively infra low frequency training. They are ranked in order of lowest pre-training score to highest. The vertical lines represent the difference between post- and pre-NF scores (i.e. the gain or lack thereof). As indicated, most of the trainees showed a positive change in their overall CPT score with most of the negative scores being less than 0.5 a standard deviation. The negative changes tend to occur in the higher performing individuals and are often non-significant.

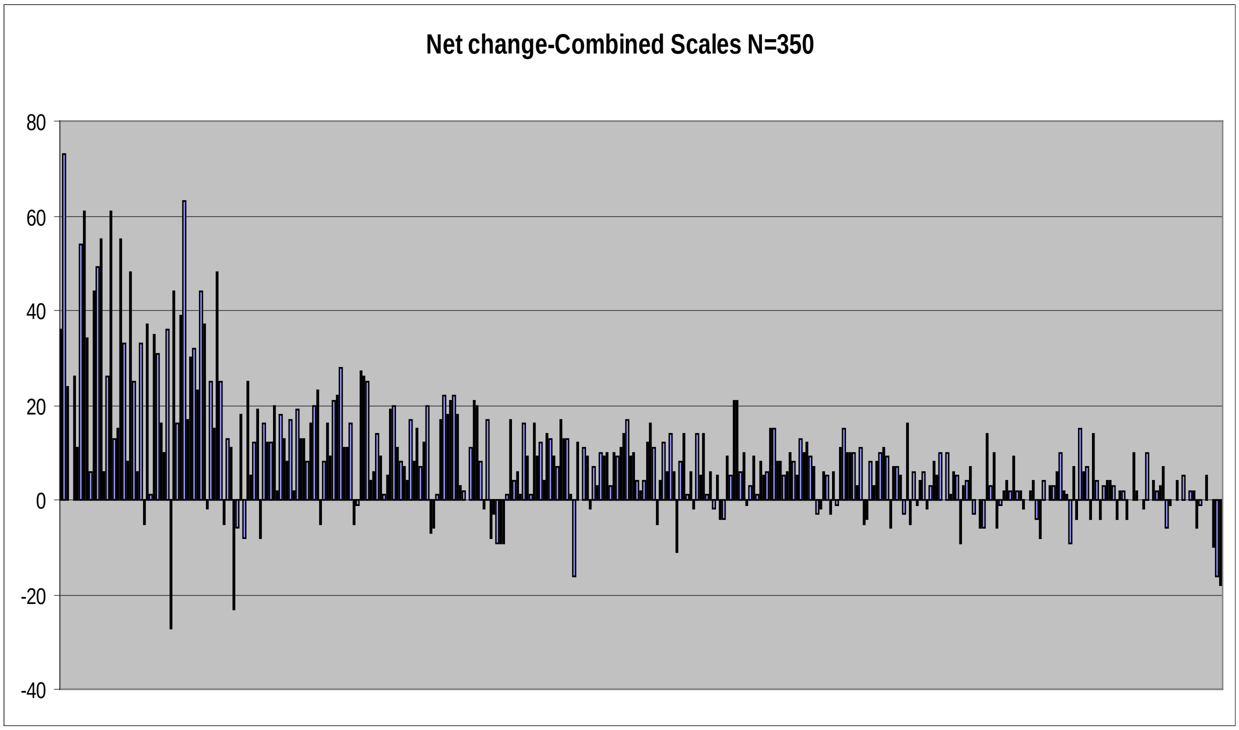

Figure 18 Combined scale score-–Net changes (N=350)

Figure 18 represents the same information as Fig. 17 but includes all 350 clients combined (the previous 249 plus the recent 101). Note that the overall shape of the change "envelope" is the same. The vast majority showed an increase in their mean CPT score following NF training, with roughly the same percent (as in Fig. 13) moving in the negative direction. Again, most of the negative changes were small (<0.5 std dev)

Combining the scales tends to smooth out the data, obscuring the dramatic outliers. But the brain adheres to the laws of uneven growth and development--which plays out in the individual dimensions of attention. Looking at each scale in isolation tells us more about each dimension but less about the global level of function of the individual. The combined scale gives us another vantage point regarding the overall improvement in CPT performance. This can be a fairly persuasive measure when the N becomes sufficiently large.

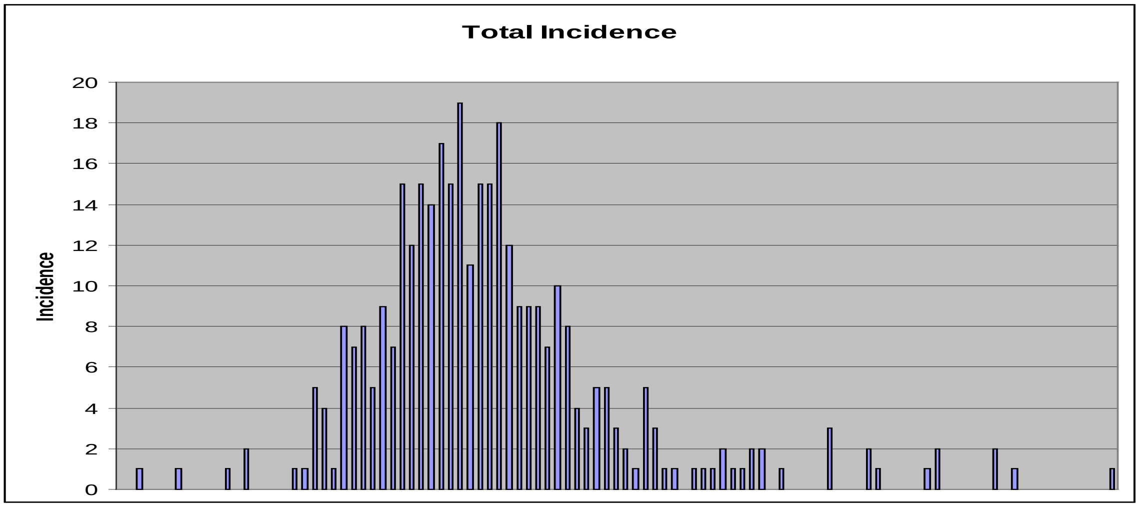

Figure 19 | | | | | | | | | | | | | | | | | |

-27 -10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70

Net Change in Std Score (Mean Change for group = 9.17)

Figure 19 represents the "incidence" of change distribution. In other words, each column represents the number of persons whose combined CPT score increased or decreased by a specific number of points (X-axis). (Note the X-axis was hand drawn and may be off by a bit.) The distribution is roughly Gaussian with long tails, the upper tail being the more prominent.

Below are the cumulative graphs for Inattention and Impulsivity (Figures 20-23). They represent the distribution for the pre- and post-training standard scores for the entire group (N=350) and those whose pre-training scores were one standard deviation below 100 (<85) –the latter being represented in percent form.

In Figure 20 we observe a substantial depression of the severely deficited end of the distribution for omission errors, with corresponding increase in the population scoring in the normal range (nominally 100+). The depletion of the deficited pool is even more apparent in Figure 21, where the cumulative incidence is shown for the deficited population (<85). If the dividing line between functional and dysfunctional is taken to be 85, then nearly 60% of the population is moved from the dysfunctional to the functional domain.

An even greater shift in the deficited pool is observed with commission errors in Figure 23. With a cutoff of 85, we observe some 75% of the population moved from dysfunctional to functional in terms of commission errors.

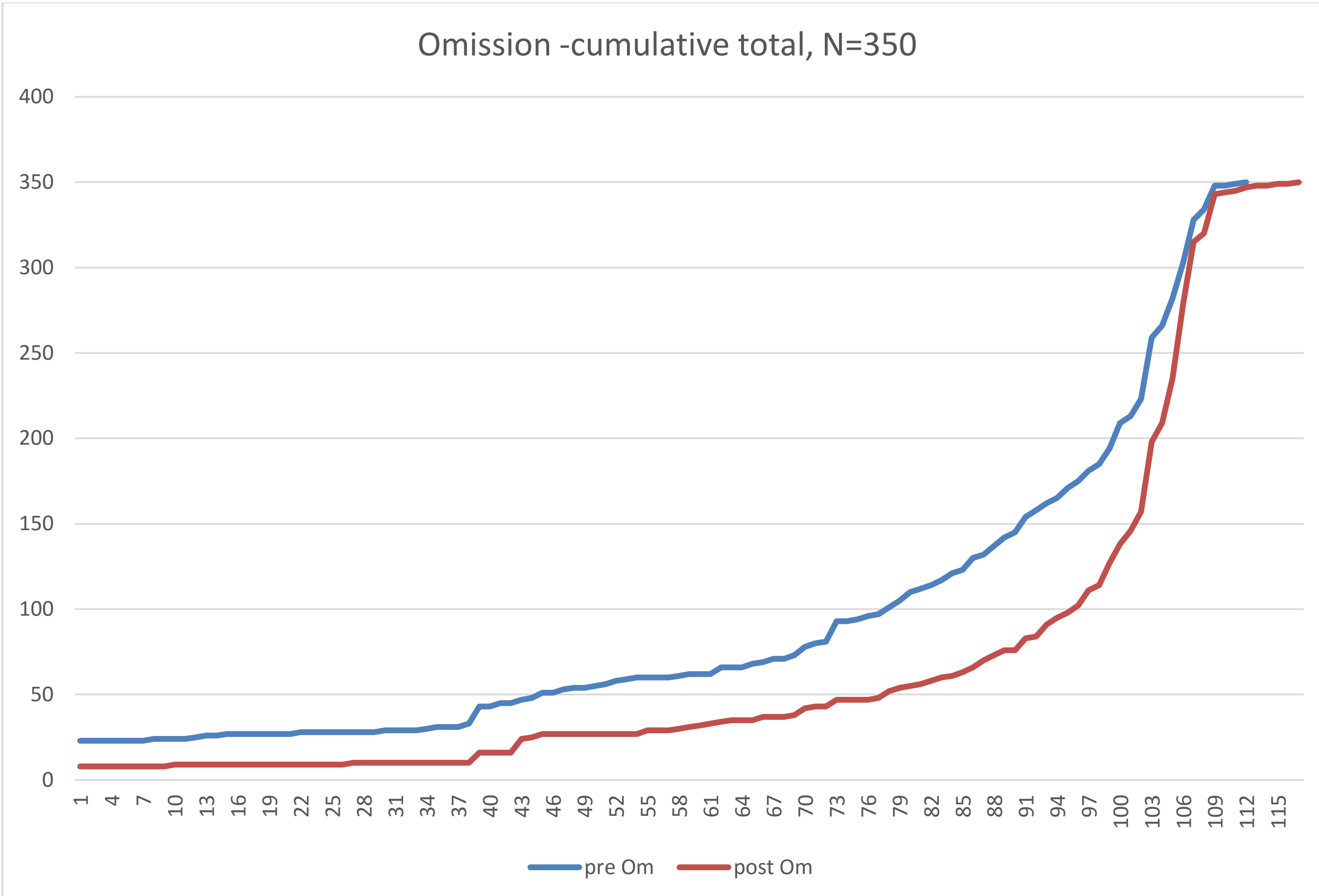
Omission -cumulative total, N=350
400
350
300
250
200
150
100
50
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91 94 97 100 103 106 109 112 115
pre Om
post Om

Figure 20

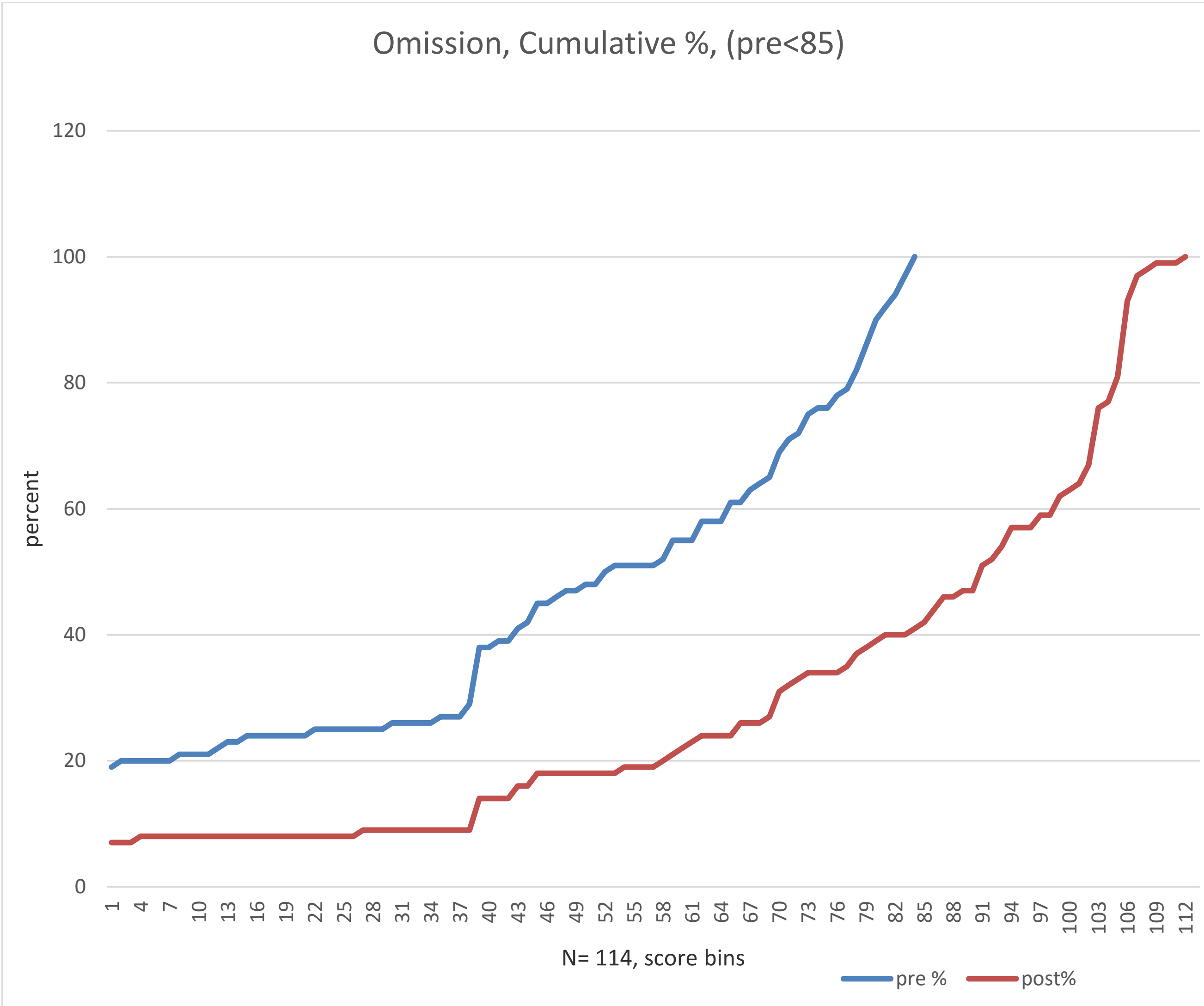
Omission, Cumulative %, (pre<85)
120
100
80
60
40
20
0
percent
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79
82
85
88
91
94
97
100
103
106
109
112
N= 114, score bins
pre %
post%

Figure 21

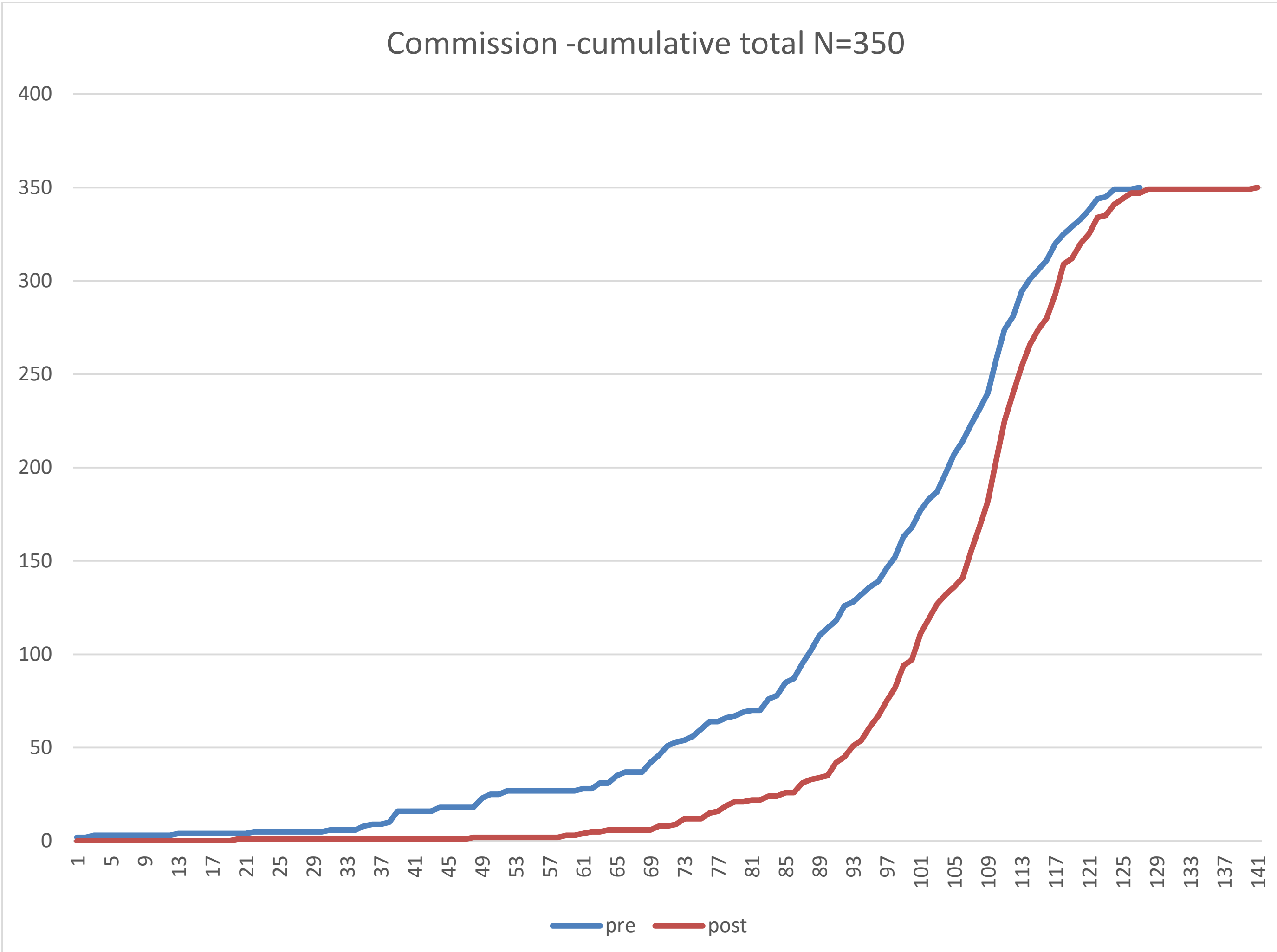
Commission -cumulative total N=350
400
350
300
250
200
150
100
50
0
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73
77
81
85
89
93
97
101
105
109
113
117
121
125
129
133
137
141
pre
post

Figure 22

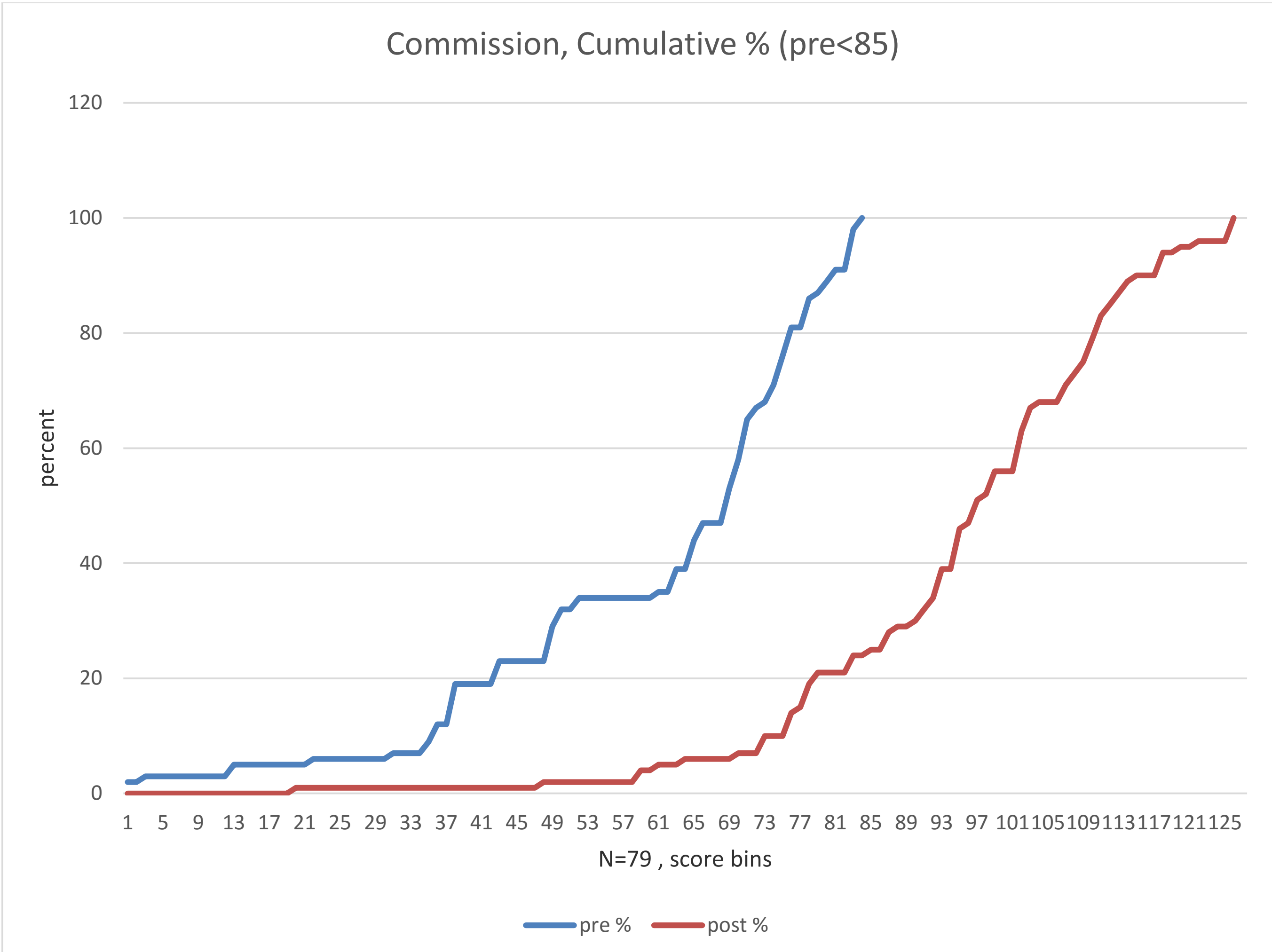

Figure 23

Discussion

Resolution of attention deficits and mood disturbances tend to occur together –as evidenced by client report coupled with CPT results. This is consistent with earlier observed results (Putman, et.al. 2005). The training also did not negatively impact those whose CPT scores were in the normal range as indicated by the generally non-significant changes in those whose pre-training scores were over 100. This is particularly evident in the combined scales graph (Figures 5 and 6). In many cases the primary symptom was not an attention deficit. Some of the other presenting syndromes were traumatic head injury, autistic spectrum disorders, depression, anxiety and insomnia. But since these disorders are often co-morbid with attention deficits, resolution of the presenting symptom correlates highly with improved attention.

Bipolar EEG training can seem confusing and counter-intuitive when considering the rewarding of exceedingly low frequencies as being beneficial. But as has been stated in earlier publications, bipolar training is fundamentally different challenge to the brain than single site-

training due to the mathematics of differential signal amplitude reinforcement and the cancellation of common mode components of the signal (Fehmi, 2002; Putman, 2002; Putman and Othmer, 2006). In the case of the infra-low-frequency reinforcement, where the individual period of a waveform can be extremely long, we have shifted back to an amplitude-driven form of training, in contrast to the more phase-involved training that prevailed for us in the EEG range. This requires further explanation because the word amplitude referred to here differs from what we call amplitude in the usual EEG training context. The amplitude referred to here is quite simply the instantaneous differential signal between the two sites. This signal is deemed to reflect the instantaneous differential cortical activation at the two sites.
The frequency selection of the program isolates a particular mechanism involved in the management of cortical activation, and the signal-tracking algorithm yields the dynamics of that signal, which is the grist for our mill. These dynamics reflect the brain's accommodation to ongoing life events, and turn out to be quite recognizable to the brain that authored the signal. Finding the individual optimal reward frequency involves some sleuthing, in that the clinician is reliant on the client's ability to convey their experience in the moment, as well as on behavioral features exhibited by the client. Measures of peripheral physiological can be additionally helpful.

All of these observations are interpreted in the context of the growing understanding of the client by the clinician. This takes full advantage of the clinician's existing skill set with respect to observing and interacting with the client. However, matters are now interpreted in terms of a physiological model that can then drive decision-making with respect to protocol optimization in terms of placement and target frequency. The training experience is therefore very interactive and engaging for both parties. The data presented here provide an incentive for a re-examination of the mechanisms of action behind neurofeedback. Infra-low frequency training as it was conducted here cannot be explained in terms of the usual operant conditioning model. Further, the training is covert, and hence cannot involve the usual cognitive mechanisms thought to be in play in neurofeedback. The effects must be explainable entirely in brain-based terms. This presents a new challenge to the field. When an existing theoretical model cannot accommodate new information, it is the model that needs to be re-evaluated. The data cannot be readily dismissed. We will soon be looking at the most recent clinic data (from 2012 onward).

Reference

Earle–Boyer, E.A., Serper, M.R., Davidson, M., Harvey, P.D. (1991). Continuous performance tests in schizophrenic patients: Stimulus and medication effects on performance. Psychiatry Research: Vol.37, No. 1. Pages 47-56.

Fehmi, L. G. (2002). Synchrony training. Journal of Neurotherapy, 5(3), 69-72.

Halpern, J. M., Sharma, V., Greenblatt, E., Schwartz, S.T. (1991) Assessment of the Continuous Performance Test: Reliability and validity in a non-referred sample. Psychological Assessment: A Journal of Consulting and Clinical Psychology, Vol. 3(4), 603-608.

S. Helps , James, C., Debener,S. , Karl A., Sonuga-Barke, E.J.S. . Very low frequency EEG oscillations and the resting brain in young adults: a preliminary study of localization, stability and association with symptoms of inattention, Journal of Neural Transmission, Vol. 115, No. 2

Leark, R. A., Dupuy, M.S., Greenberg, L.M., Corman, C.L. and Kindschi, C.L. (2007). TOVA: Test of Variables of Attention, Professional Guide. Los Alamitos, CA: Universal Attention Disorders Inc.

O'Leary J.L., Goldring, S. (2007) Slow cortical potentials their origin and contribution to seizure discharge. Epilepsia, Vol.1, Issue 1-5, 561-574.

Othmer, S. F. Protocol Guide for Neurofeedback Clinicians,3rd edition (2010). Published by EEG Info, Woodland Hills, California.

Othmer, S. F. Protocol Guide for Neurofeedback Clinicians, 5th edition (2015). Published by EEG Info, Woodland Hills, California.

Othmer, S.F. (2005) Inter-hemispheric EEG training, Journal of Neurotherapy, Vol.9 (2)

Othmer, S. , Othmer S.F. , (2006) Infra-Low Frequency Training. EEG Info Publications, Woodland Hills, CA.

Putman, J.A. (2002). Technical issues involving bipolar EEG training protocols. Journal of Neurotherapy, Vol. 5(3), 51-58.

Putman, J.A., Othmer, S.F., Othmer, S., Pollock, V.E. (2005). TOVA Results Following Inter-hemispheric Bipolar EEG training, Journal of Neurotherapy, Vol.9 (1), 37-52.

Putman J.A., Othmer S. (2006). Phase Sensitivity of Bipolar EEG training protocols, Journal of Neurotherapy Vol. 10 (1), 73-79.

Rapport M.D., Jones J.T., DuPaul, G.J. (1987) Attention deficit disorder and methylphenidate: group and single subject analyses of dose effects on attention in clinic and classroom settings. Journal of Clinical Child Psychology, 16, 329-338.

Riccio, C.A., Waldrop, J.M., Reynolds, C.R., Lowe, P. (2001) Effects of Stimulants on Continuous Performance Test (CPT), J Neuropsychiatry Clin Neuroscience, 13, 326-340.

Simo Monto, Satu Palva, Juha Voipio, and J. Matias Palva, (2008). Very Slow EEG Fluctuations Predict the Dynamics of Stimulus Detection and Oscillation Amplitudes in Humans. The Journal of Neuroscience, 28(33), 8268-8272.