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Abstract

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Degree Type

Thesis

THE EFFECTS OF PRISM-INDUCED BINOCULAR STRESS ON P-300 EVENT RELATED POTENTIALS

by
Barbara L Dirks, O.D.

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For the Degree
Master of Education
in
Visual Function in Learning

Committee Members:

Robert L. Yolton, O.D., Ph.D., Chair
Anita McClain, Ed.D.
Daiva A. Banaitis, Ph.D., P.T.

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Key Words: P-300, P-3, Prism Stress, Prism, Prism Reader Effect, Latency, Phoria, Duction, Blur, Diplopia, Cognitive Processing, Mental State.

ACKNOWLEDGEMENTS

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ABSTRACT

The latency of the P-300 event related potential is affected by various factors, the most important of which is the ease of interpreting information conveyed by the stimulus. Using an odd-ball paradigm in which 20% women's names and 80% men's names were presented sequentially on a video monitor, P-300's were obtained from 15 normal subjects. Names were presented under four different viewing conditions: habitual, horizontal phoria neutralized, and with maximum base-in and base-out prism values which still allowed clear, single vision. Results showed that mean P-300 amplitudes did not differ significantly across viewing conditions. There was, however, a significant increase in the mean latencies for the phoria neutralized and base-in and base-out viewing conditions as compared to the habitual viewing condition. Using the P-300 as a measure of cognitive processing speed, this experiment indicates that there is a significant slowing of information processing when normal binocular function is disrupted with prisms.

INTRODUCTION

It is generally accepted that binocular stress is created when some aspect of the visual system is postured outside of the "zone of comfortable binocular vision". (1) Some parameters of this comfort zone can be measured by phoria and duction relationships. In prism duction studies, blur of the target and diplopia (break) are used as indications of the limits of stress the binocular system can tolerate. There are, however, more subtle indicators of binocular stress that can be demonstrated prior to reaching the blur level. One of these is a subjective response often described as an increased difficulty in concentration. (2) This phenomena has been referred to as the Prism Reader Effect because it is often elicited from patients when they are working with that piece of binocular training equipment. (2) The effect can also be demonstrated with loose prisms, and, in fact, is frequently used by optometrists to show parents and teachers the stress some children endure when trying to read with misaligned vergence systems.

The Prism Reader Effect can be produced when target words and letters are seen as clear and single. The subjects or patients describe the effect as a feeling of mental confusion and may comment that the task is "getting harder" or the reading material "doesn't make sense anymore". Though some theories have been advanced to explain how prism stress might produce these cognitive effects, there is still not an accepted explanation of the phenomenon.

The Prism Reader Effect can be measured by noting a reduction in reading rates and comprehension on standardized reading tests when prism stress is created. (2) The effect also seems to reduce a subject's decision making abilities in discrimination tasks. If binocular stress is actually affecting the patient's or subject's ability to mentally process information, then there might be a measurable effect on the brain waves (electroencephalographic (EEG) signals) associated with this mental processing.

Among the brain waves produced during mental processing of the information content of a stimulus is a large amplitude, positive polarity potential. (3,4) Because under some testing conditions this wave peaks around 300 ms after a stimulus is delivered, it is referred to as the P-300 or positive wave with a 300 ms latency. (5-7) Because it is also the third major positive wave generally seen following a visual stimulation, it is therefore referred to as the P-3. P-300 is somewhat of a misnomer due to the fact that the latency or delay of the P-300 after a stimulus can be 700 ms or more depending on the time the brain takes to process the stimulus. (8)

Though there are many locations from which a P-300 can be recorded, (9) in this study a recording electrode was placed on the scalp centrally above the parietal region of the brain (location designation Pz). This brain region is associated with short term memory processing.

The P-300, rather than being an evoked response to the stimulus, is actually generated during the cognitive processing of a stimulus. (4,5,7) In theory, when a series of words or numbers in a specific category is presented to a subject, a template or pattern of the expected category is formed in short term memory. Then, if a stimulus is presented which does not match the template, a change in the template is required and resultant mental activity produces a P-300. The novel stimulus is often referred to as an "odd-ball" and odd-ball paradigm experiments in which many stimuli in one category are presented along with a few stimuli (e.g., 20%) in another category are commonly used to elicit P-300s. (7)

Because individual P-300s are very small electrical potentials, averaging signals produced by a number of odd-ball stimuli are required to produce a reliable P-300 wave. The amplitudes and latencies of averaged P-300s obtained under various stimulus conditions can be compared to assess changes in mental processing.

The amplitude of the P-300 is affected by the relative frequency of the odd-ball presentation, the amount of attention the subject paid to the task and the value or significance of the stimuli. (6,8)

A number of stimulus conditions have been shown to affect the latency of this potential (8,10), most important of which is the length of time required by the subject to determine if the stimulus was expected or novel. (7,11) For example, decreasing the letter size and/or the degree of target clarity increases P-300 latency. (12) Therefore, the latency provides an indication of the processing and categorizing time required for a stimulus. (7,8)

The purpose of the project described below was to objectively determine if binocular stress would affect discrimination and processing time for the information content of stimulus words even though the words remained visually clear and single. To make this determination, normal subjects were asked to view a series of names presented one at a time on a video monitor. Twenty percent of the names were novel (odd-balls), and P-300's were averaged for these names. Subjects viewed the name lists with their habitual correction, with prisms that corrected their phorias, and with the maximum base-in and base-out prisms that the subjects could tolerate without diplopia or blur. P-300 latencies were then compared across viewing conditions to determine if the addition of prism stress slowed the mental processing and categorization of the names.

SUBJECTS AND METHODS

Subjects

The subjects were 15 optometry students at Pacific University, 10 men and 5 women, ages 21 to 34. All had best corrected visual acuity of 6/6 (20/20) at six meters and 50 cm, normal binocularity as indicated by previous visual exams, low exophorias at the 50 cm testing distance and ductions within the accepted range of normal according to Sheard's and Percival's criteria. (13-15) Each subject completed a consent form which briefly explained the purpose of the project.

Just prior to data recording, subjects were tested at 50 cm to determine their visual acuities, phorias, and base-in and base-out ductions. The phorias and ductions were measured using an 40 column size letter on the video display terminal (VDT) as a target.

Stimuli

Stimulus word lists were generated by an Apple IIe computer and displayed 50 cm in front of the seated subjects on an Apple monochrome VDT (green letters on a dark background) in 40 column size letters. The 6.5 by 2.5 cm center area of the screen was surrounded by a rectangle of asterisks (***) with a horizontal line of asterisks contained within this area to indicate the location at which the stimulus names would be presented. During each trial (name presentation) the central asterisks were replaced by either a man's name (common stimulus) or a women's name (novel or odd-ball stimulus). The name was presented for 100 msec and then replaced by the asterisks. Trials were separated by 1.5 sec periods.

A list of 322 men's and women's names was generated and then randomized into four variations. Care was taken to insure that the names were not culturally biased nor sex ambigious. Each list contained 80% men's names and 20% women's names. The placement of the uncommon stimuli was randomized with the constraint that no more than 10 nor less than 4 men's names were presented between each woman's name.

Viewing Conditions

Each subject was placed behind a phoropter with their habitual near lens power in the banks. For all viewing conditions, the Risley prisms were in place. During the habitual condition, the prisms were set at zero power. Each subject viewed the name lists under habitual viewing conditions, with base-in prism set at 2 prism diopters (pd) less than the blur point measured at 50 cm, with base-out prism set at 2 pd less than the blur point measured at 50 cm, and with their habitual horizontal phoria at 50 cm neutralized (a condition designed to be "stress free"). The order of presentation of conditions was randomized to reduce the effects of either fatique or familarization factors. To insure that there was no blurring of the stimuli, visual acuity was retested prior to obtaining data for each viewing condition. Subjects were questioned between each of the viewing conditions and all reported that the stimuli stayed clear and single.

To maintain attention on the task and to increase the P-300 amplitudes, subjects were asked to mentally count the number of odd-ball presentations.

Recording and Data Analysis

Silver/silver-chloride electrodes were placed on the forehead (ground), both earlobes (linked reference) and at location Pz (lateral midline of the head, one-third of the nasion-inion distance above the inion). Subjects were interfaced through a Gould Universal Isolation amplifier to a Data General Nova 800 computer. Amplifier frequency limits were 0.3 and 30.0 Hz. Inter-electrode resistances were less than 5 Kohms. The output from the amplifier was displayed on an oscilloscope and recorded on a Vetter model C-4 FM tape system.

The Apple IIe sent synchronizing pulses to the tape recorder and the Data General computer to signal the start of each trial and to indicate whether a common or uncommon stimulus was to be presented. After the Apple signaled the start of a trial, the EEG signals were digitized every 2.0 msec until 512 points (1024 msec) had been converted. Signals corresponding to fifty presentations of women's names were ensemble averaged for each viewing condition and the Data General determined the amplitude and latency of the P-300 peak. This process was repeated for each subject/viewing condition combination.

RESULTS

Figure 1 shows ensemble averaged P-300 waveforms from one subject. Note the predominant P-300 peaks and the latency shift for the data obtained in the habitual viewing condition versus the data obtained in the other viewing conditions. (Because of different amplitude scaling factors used to obtain these curves, their amplitudes cannot be compared directly on the Figure. The typical P-300 signal amplitude is about 20 uV.) Because of equipment limitations, composite curves showing data combined across subjects could not be presented.

Table 1 shows summary and source tables resulting from a single factor repeated measures analysis of variance (ANOVA) of the P-300 amplitude data produced by the fifteen subjects. The table shows that there was no significant difference in P-300 amplitudes across viewing conditions. This suggests that the subjects' attention did not vary significantly across viewing conditions and that they detected and responded to most or all women's names. Further evidence for this is provided by the fact that no subject's count of women's names was off by more than two for any viewing condition.

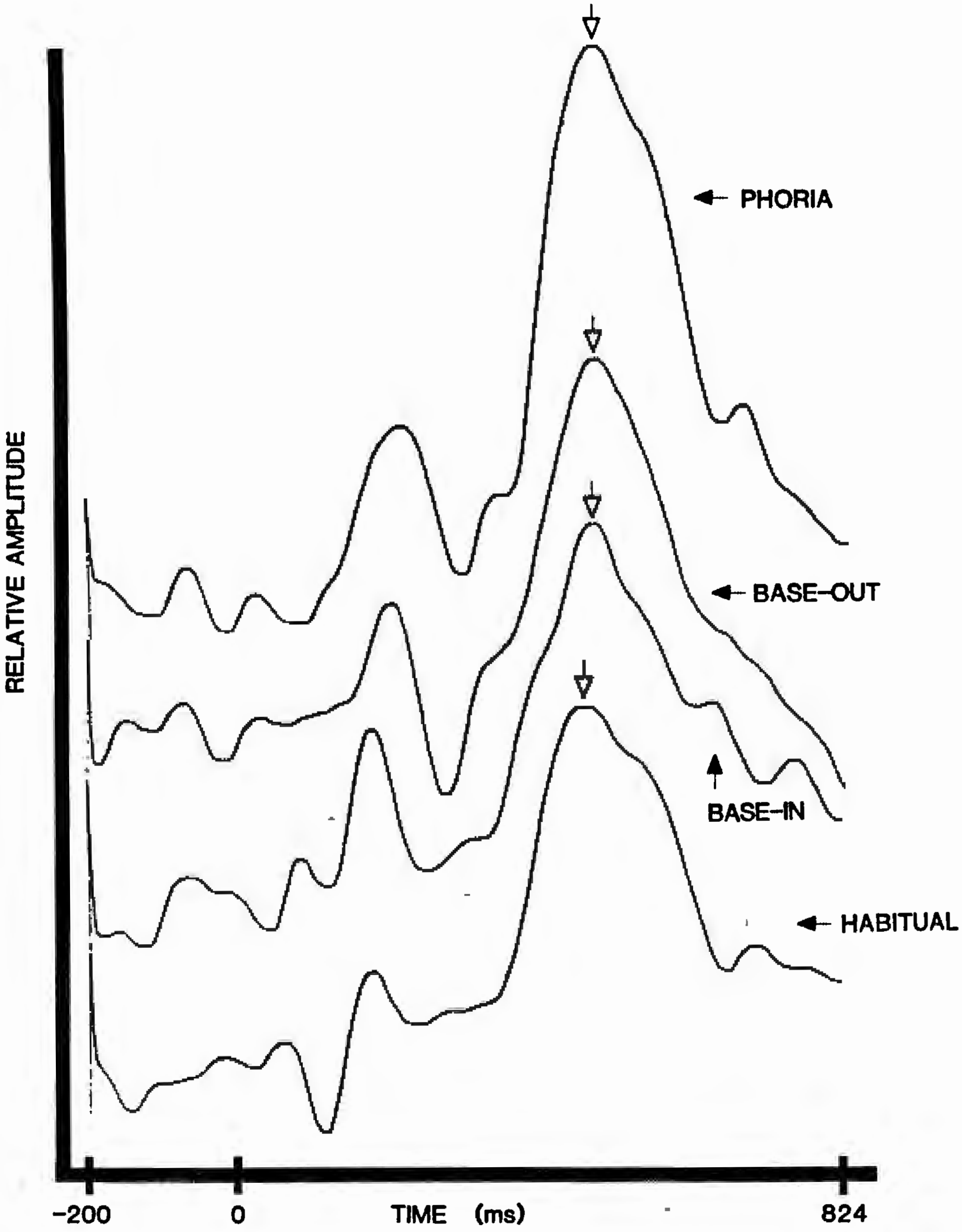

Figure 1: Example ensemble averaged P-300 waveforms from one subject for the various viewing conditions. The open arrows indicate the peaks of the p-300 waves. Amplitudes have been scaled independently for the different viewing conditions thus cannot be compared directly. Waveforms have been separated vertically on the figure for ease of interpretation.

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
HABITUAL	15	14564.8	4265.601	1101.373
BASE-OUT	15	13012.667	4795.475	1238.186
BASE-IN	15	14186.4	5664.931	1462.679
PHORIAS	15	14605.8	7739.435	1998.313

Source:	df:	Sum of Squares:	Mean Square:	F-test:	P value:
Between subjects	14	1.384E9	98874068.31	8.806	1.0E-4
Within subjects	45	505235196.25	11227448.806		
treatments	3	24921020.85	8307006.95	.726	.542
residual	42	480314175.4	11436051.795		
Total	59	1.889E9			

Table 1: Summary (upper) and analysis of variance source (lower) tables for P-300 amplitudes. Amplitude values are in computer scale units. In the source table, "treatments" refers to the different viewing conditions.

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
HABITUAL	15	509.6	33.672	8.694
BASE -OUT	15	531.2	36.575	9.444
BASE -IN	15	532.4	38.908	10.046
PHORIA	15	529.333	34.539	8.918

Source:	df:	Sum of Squares:	Mean Square:	F-test:	P value:
Between subjects	14	53890.433	3849.317	7.272	1.0E-4
Within subjects	45	23819.5	529.322		
treatments	3	5213	1737.667	3.922	.0148
residual	42	18606.5	443.012		
Total	59	77709.933			

Comparison:	Mean Diff.:	Scheffe F-test:
HABITUAL vs. BASE -OUT	-21.6	2.633*
HABITUAL vs. BASE -IN	-22.8	2.934*
HABITUAL vs. PHORIA	-19.733	2.197*
BASE -OUT vs. BASE -IN	-1.2	8.126E-3
BASE -OUT vs. PHORIA	1.867	.02
BASE -IN vs. PHORIA	3.067	.053

Table 2 Summary (upper), ANOVA source (middle) and Scheffe (lower) analysis tables for the P-300 latency data expressed in msec. The ANOVA indicates that the treatment (viewing conditions) effect is significant at the 0.05 level. For the Scheffe tests, astericks indicate that the latency for the habitual viewing conditions differed significantly at the 0.10 level from the latencies for the other viewing conditions.

Table 2 shows summary, ANOVA source and Scheffe analysis tables for the latency data. The source table indicates that there is a significant ($p < 0.05$) viewing condition effect present in the data. Follow-up testing using the Scheffe method shows that the latency for the habitual condition was significantly ($p < 0.10$) shorter (by about 20 msec) as compared to the latencies for the other viewing conditions. The Scheffe tests also show that the latencies did not differ significantly between the phoria compensated, base-in and base-out viewing conditions. These results are consistent with subject comments which indicated that all of the prism viewing conditions were "harder to do" and required more "stress" and "energy" as compared to the habitual condition.

DISCUSSION

The purpose of this project was to demonstrate that prism stress would cause a decrease in mental processing speed consistent with reports of confusion and reduced ability to function when visual stimuli were viewed through prisms. The results confirm that, as measured by the P-300, base-in and base-out stress does slow processing.

A more surprising result was found for the phoria neutralization viewing condition. It would be assumed that allowing the subjects' eyes to "float" to their position of rest would relieve any fusion stress present and allow maximum possible processing speed. However, the results presented above indicate that is not the case. Phoria neutralizing prisms increased processing time just as much as the stressing prisms did. It would, therefore, appear that any short term disruption of the habitual binocular state in these adult subjects stresses the cognitive process and slows processing.

The disciplines involved with various aspects of information processing have all found that stress of various kinds can disrupt the learning process. Educators go to great lengths to make the learning environment as comfortable as possible for the learner. Psychologists measure processing breakdown in sleep deprivation and distracting noise studies. Developmental optometrists have linked performance difficulties and some reading problems to binocular stress. (16) Vision therapy for poor readers is based upon reducing the stress related to the act of reading or learning. Many developmental or behavioral optometrists believe that the fusional state is an indicator of visual system adjustments made to environmental (stress) factors. (16-18) Reading requires a constant coordination of both eyes and any disruption in fusional posture results in symptoms ranging from subtle to overt. Reading delayed students often display characteristic symptoms of binocular stress. (19) "Stress brings up a constriction of the perceptual fields, and the child observes less, sees less, remembers less, learns less, and becomes generally less efficient." (20)

If indeed binocular stress increases the processing time as demonstrated in this study, then the reverse might also be true; long-term or short-term reduction of stress might decrease processing time and improve performance. This hypothesis remains to be investigated, but it seems to follow logically from the results of the present study.

There are, however, several unknown factors left at the conclusion of this study. The duration of the prism effect is unknown, and it is not known what would happen if the prism stress was built up gradually over time. With most true binocular stress patients, a high phoria is thought to be a compensation for other "out-of-balance" components of the visual system and often develops slowly. (18)

Since subjects were stressed to within two prism diopters of their blur points, the effects, if any, of small levels of prism stress are also unknown. The results of the phoria neutralization, however, seem to indicate that even a small amount of change is enough to disrupt cognitive processing (at least temporarily).

Future studies should be pursued to determine if a reverse of this effect can be demonstrated. Subjects who are diagnosed as convergence or divergence binocular dysfunction patients should be measured in their habitual (stressed) conditions and then with the stress relieved by application of appropriate prisms or vision therapy. Positive short and long term improvement in cognitive processing (as measured by reduction of P-300 latencies) would lend much credence to these forms of treatment for reading/learning disabled patients whose problems are caused by binocular stress.

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APPENDIX I

DATA SUMMARY FOR ALL SUBJECTS

PRISM READER STUDY FINAL DATA 10-7-86

P-300 LATENCY

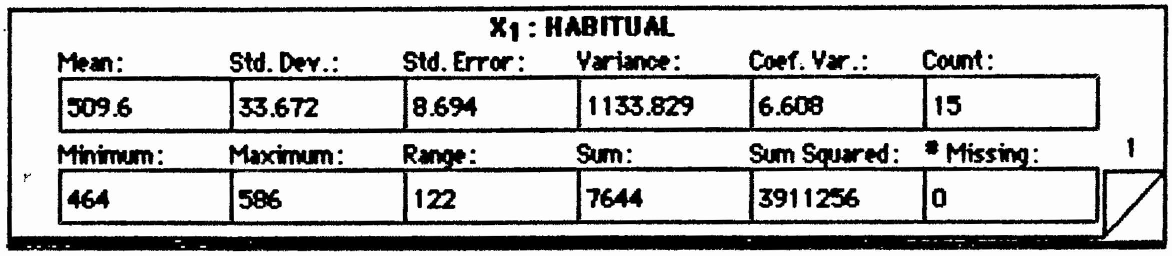
HABITUAL	BASE-OUT	BASE-IN	PHORIA
528.0	554.0	506.0	588.0
482.0	520.0	488.0	502.0
508.0	550.0	516.0	484.0
498.0	514.0	524.0	512.0
484.0	506.0	518.0	516.0
494.0	516.0	532.0	526.0
466.0	514.0	514.0	482.0
500.0	516.0	510.0	520.0
512.0	485.0	534.0	514.0
564.0	594.0	592.0	568.0
464.0	512.0	534.0	540.0
526.0	490.0	466.0	514.0
500.0	512.0	556.0	516.0
586.0	590.0	596.0	564.0
532.0	595.0	600.0	594.0

P300-AMPS

HABITUAL	BASE-OUT	BASE-IN	PHORIA
15407.0	4772.0	14623.0	4048.0
17457.0	17181.0	16929.0	19491.0
11236.0	9771.0	10890.0	17042.0
11449.0	13376.0	3132.0	9857.0
11352.0	10762.0	12313.0	8011.0
26792.0	22536.0	25880.0	36582.0
17675.0	14816.0	15391.0	16974.0
16305.0	14199.0	12986.0	13907.0
10915.0	13495.0	16286.0	14660.0
15867.0	19269.0	16423.0	21481.0
11793.0	16758.0	17068.0	15677.0
10739.0	12780.0	14335.0	10950.0
11411.0	5885.0	4865.0	8456.0
13518.0	9228.0	10580.0	8124.0
16556.0	10362.0	21095.0	13827.0

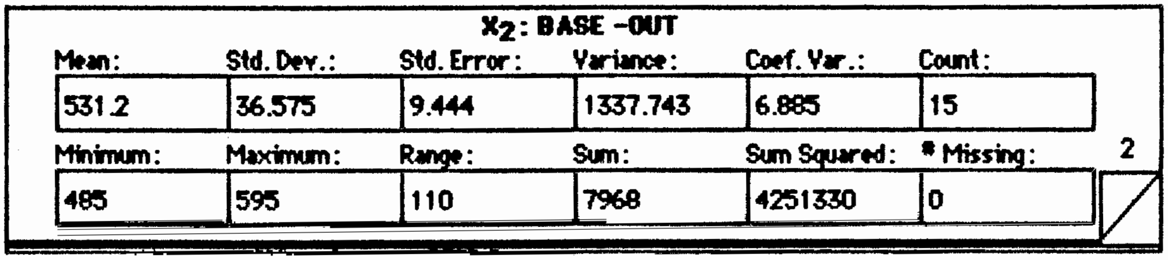
APPENDIX II

ANALYSIS OF VARIANCE PRINTOUTS



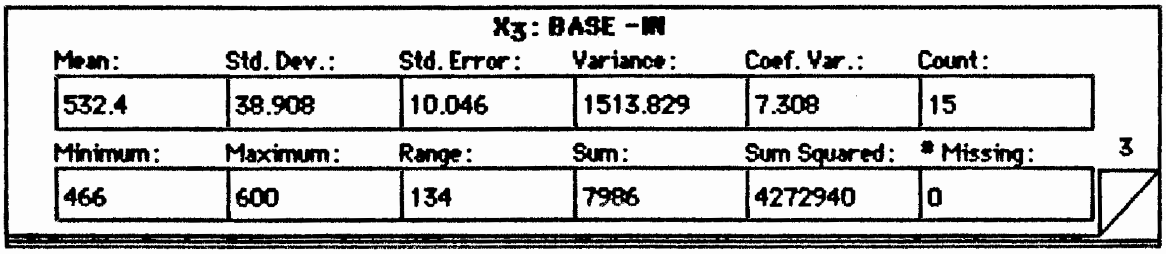
X_1 : HABITUAL

Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
509.6	33.672	8.694	1133.829	6.608	15
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum Squared:**	**# Missing:**
464	586	122	7644	3911256	0



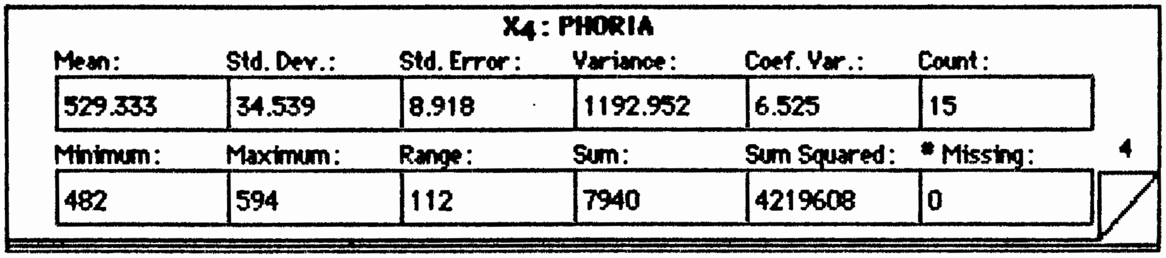
X_2: BASE -OUT

Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
531.2	36.575	9.444	1337.743	6.885	15
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum Squared:**	**# Missing:**
485	595	110	7968	4251330	0



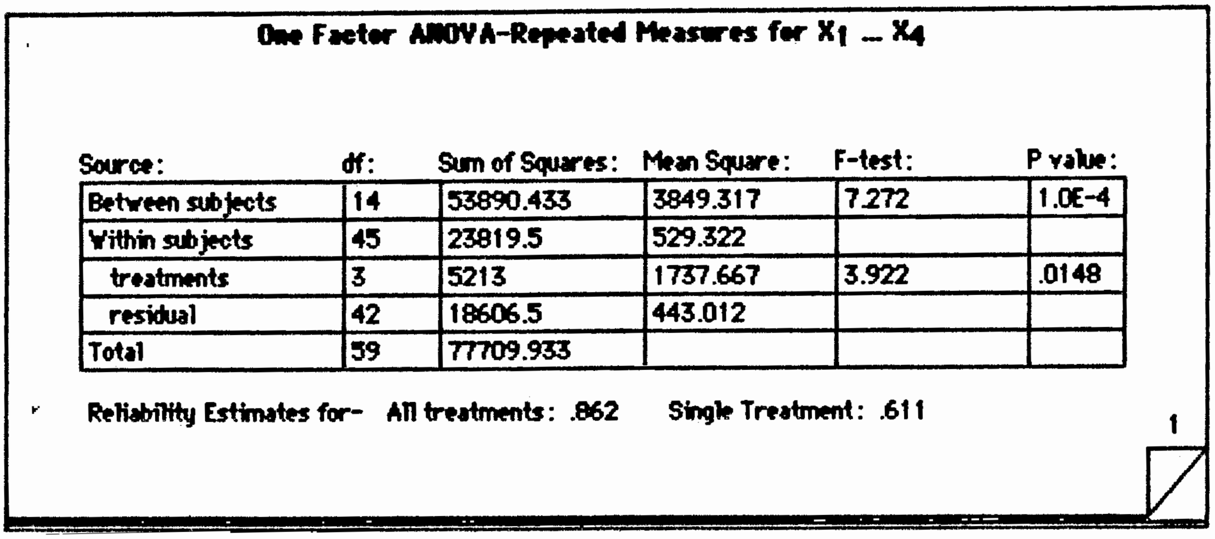
X_3: BASE -IN

Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
532.4	38.908	10.046	1513.829	7.308	15
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum Squared:**	**# Missing:**
466	600	134	7986	4272940	0



X_4: PHORIA

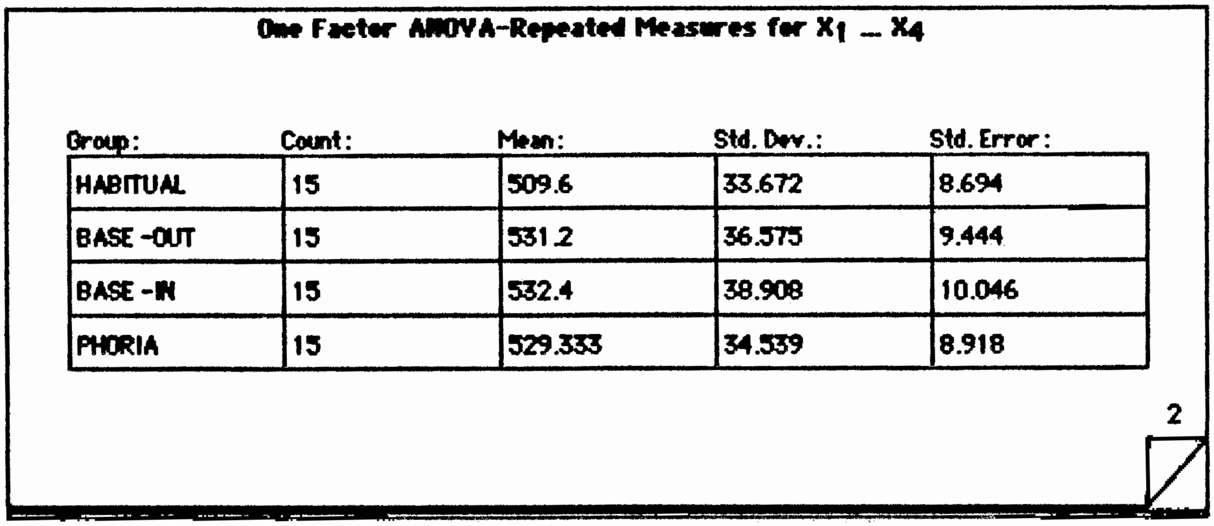
Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
529.333	34.539	8.918	1192.952	6.525	15
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum Squared:**	**# Missing:**
482	594	112	7940	4219608	0



One Factor ANOVA-Repeated Measures for X_1 ... X_4

Source:	df:	Sum of Squares:	Mean Square:	F-test:	P value:
Between subjects	14	53890.433	3849.317	7.272	1.0E-4
Within subjects	45	23819.5	529.322		
treatments	3	5213	1737.667	3.922	.0148
residual	42	18606.5	443.012		
Total	59	77709.933			

Reliability Estimates for- All treatments: .862 Single Treatment: .611



One Factor ANOVA-Repeated Measures for X_1 ... X_4

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
HABITUAL	15	509.6	33.672	8.694
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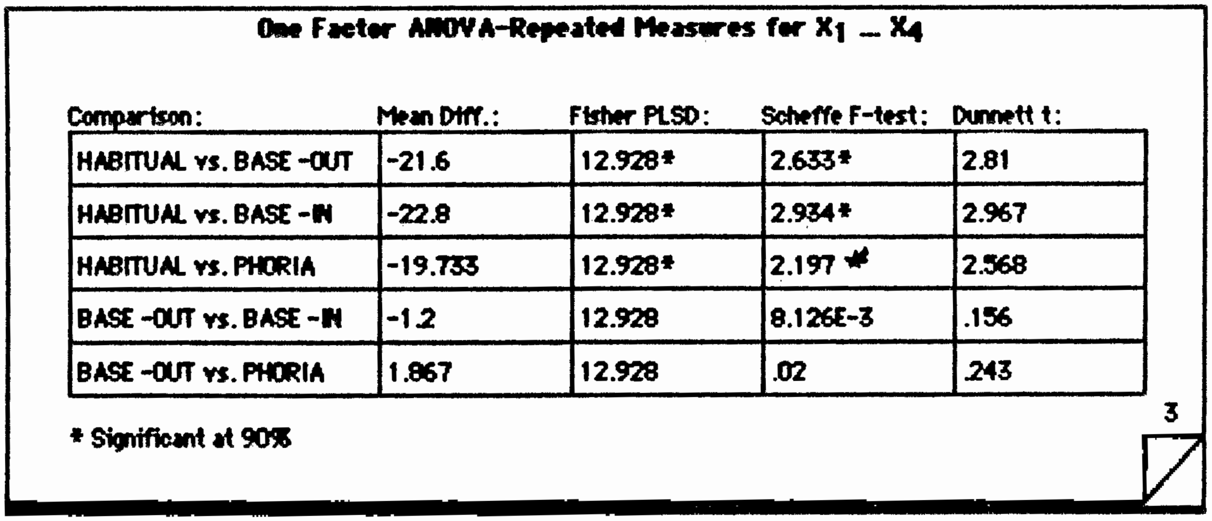
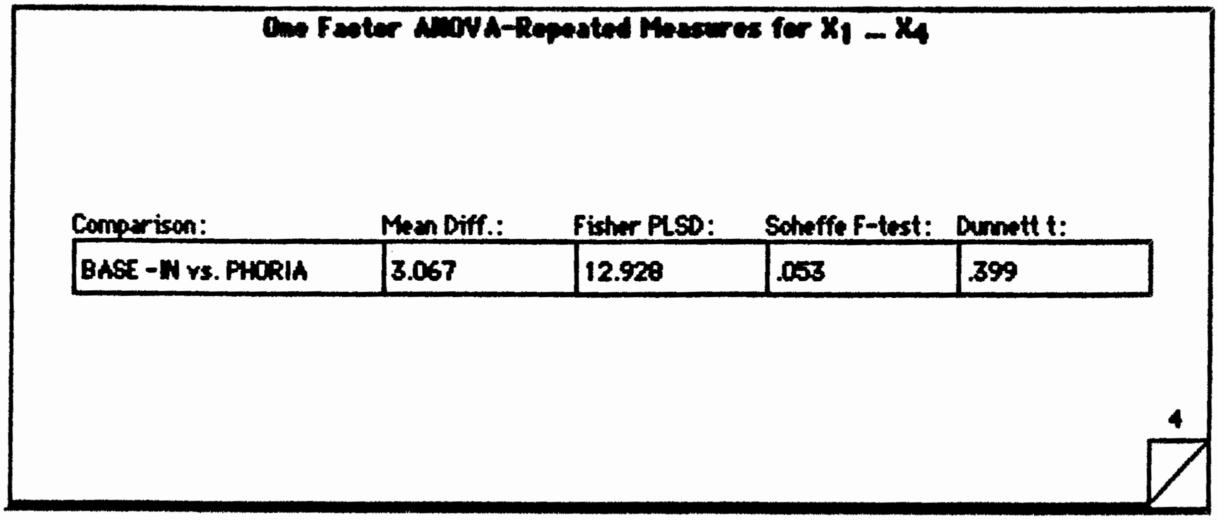


One Factor ANOVA-Repeated Measures for X_1 ... X_4

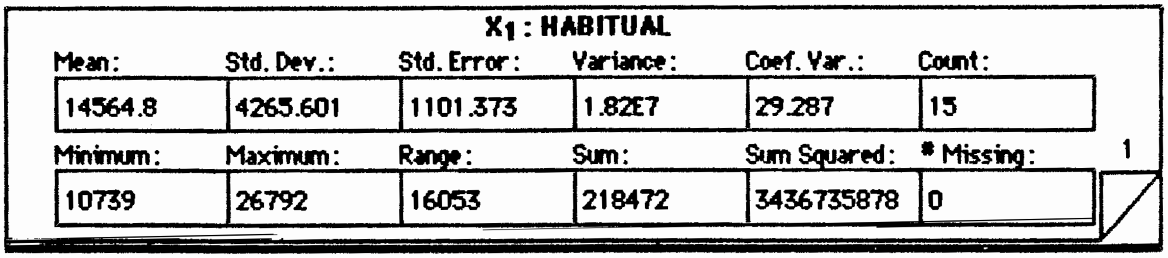
Comparison:	Mean Diff.:	Fisher PLSD:	Scheffe F-test:	Dunnett t:
HABITUAL vs. BASE-OUT	-21.6	12.928*	2.633*	2.81
HABITUAL vs. BASE-IN	-22.8	12.928*	2.934*	2.967
HABITUAL vs. PHORIA	-19.733	12.928*	2.197 *	2.568
BASE-OUT vs. BASE-IN	-1.2	12.928	8.126E-3	.156
BASE-OUT vs. PHORIA	1.867	12.928	.02	.243

* Significant at 90%



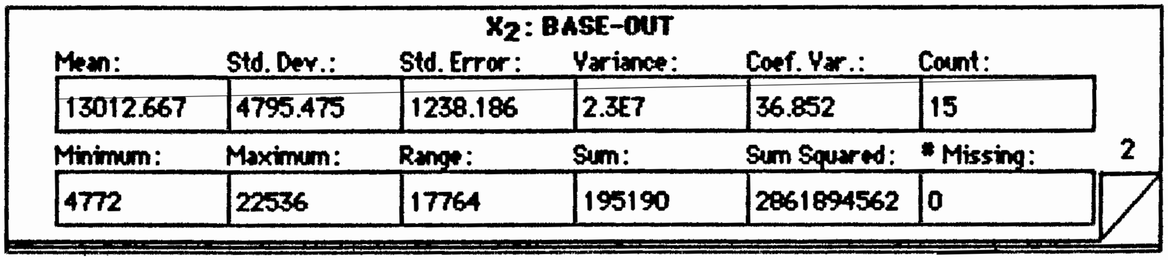
One Factor ANOVA-Repeated Measures for X_1 ... X_4

Comparison:	Mean Diff.:	Fisher PLSD:	Scheffe F-test:	Dunnett t:
BASE -IN vs. PHORIA	3.067	12.928	.053	.399



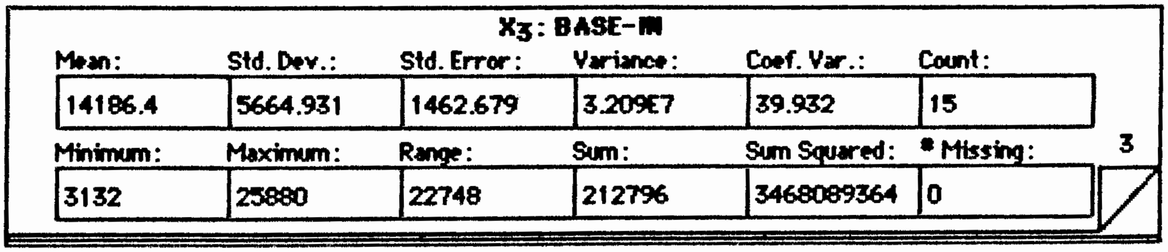
X_1 : HABITUAL

Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
14564.8	4265.601	1101.373	1.82E7	29.287	15
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum Squared:**	**# Missing:**
10739	26792	16053	218472	3436735878	0



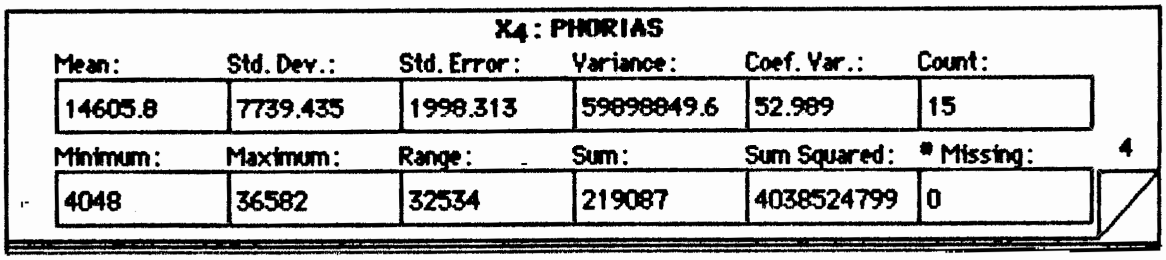
X_2 : BASE-OUT

Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
13012.667	4795.475	1238.186	2.3E7	36.852	15
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum Squared:**	**# Missing:**
4772	22536	17764	195190	2861894562	0



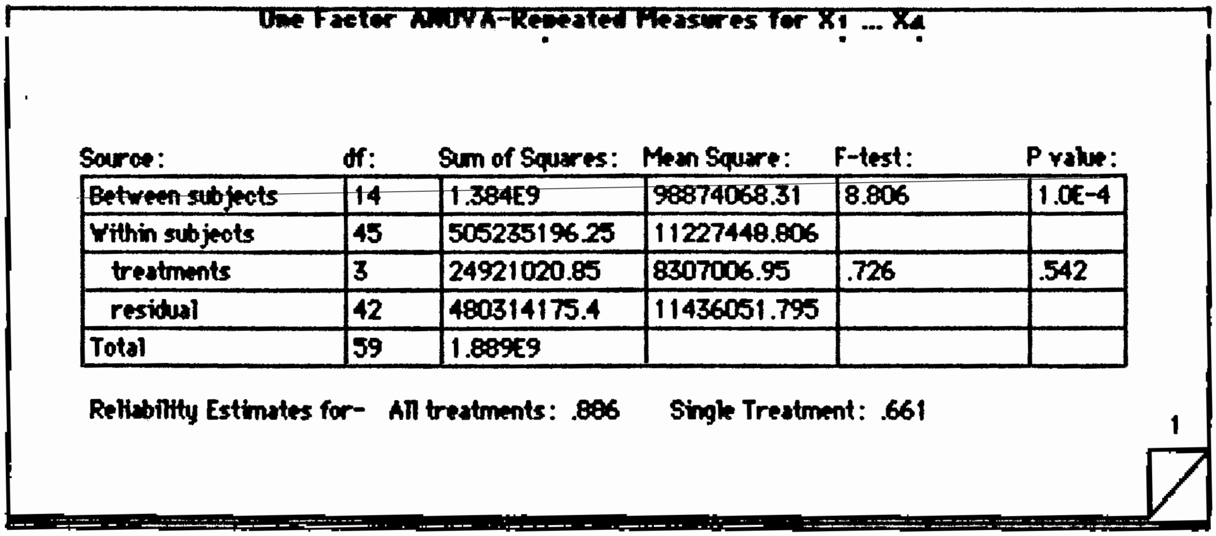
X_3 : BASE-IN

Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
14186.4	5664.931	1462.679	3.209E7	39.932	15
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum Squared:**	**# Missing:**
3132	25880	22748	212796	3468089364	0



X_4 : PHORIAS

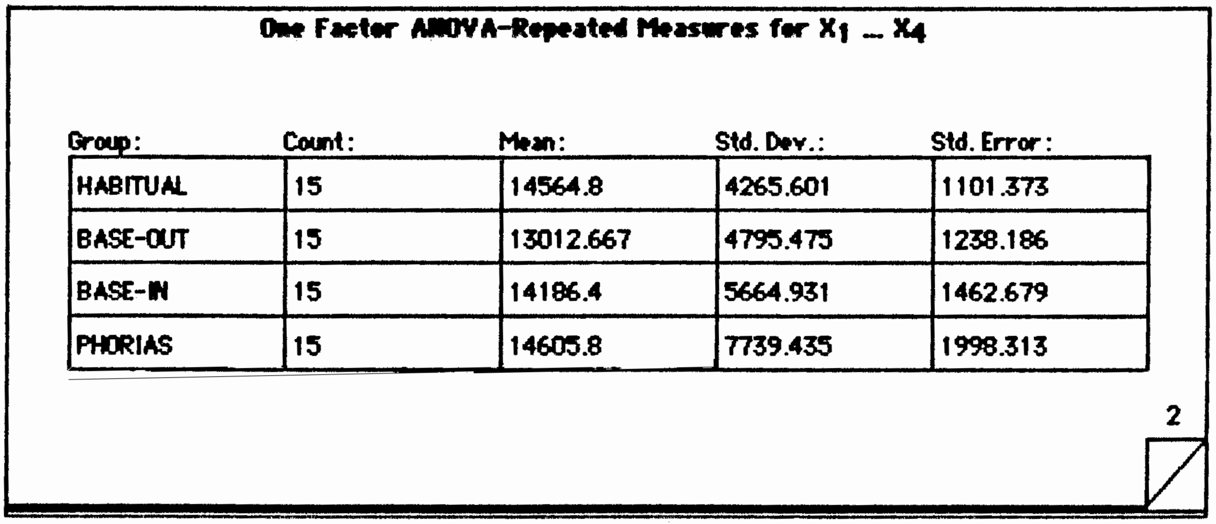
Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
14605.8	7739.435	1998.313	59898849.6	52.989	15
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum Squared:**	**# Missing:**
4048	36582	32534	219087	4038524799	0



One Factor ANOVA-Repeated Measures for X_1 ... X_4

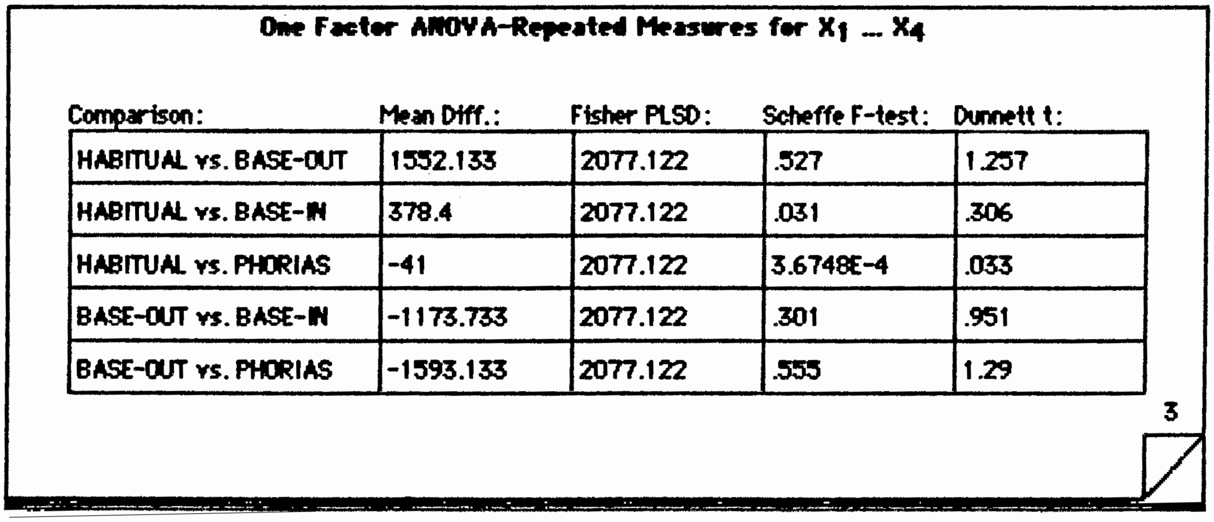
Source:	df:	Sum of Squares:	Mean Square:	F-test:	P value:
Between subjects	14	1.384E9	98874068.31	8.806	1.0E-4
Within subjects	45	505235196.25	11227448.806		
treatments	3	24921020.85	8307006.95	.726	.542
residual	42	480314175.4	11436051.795		
Total	59	1.889E9			

Reliability Estimates for- All treatments: .886 Single Treatment: .661



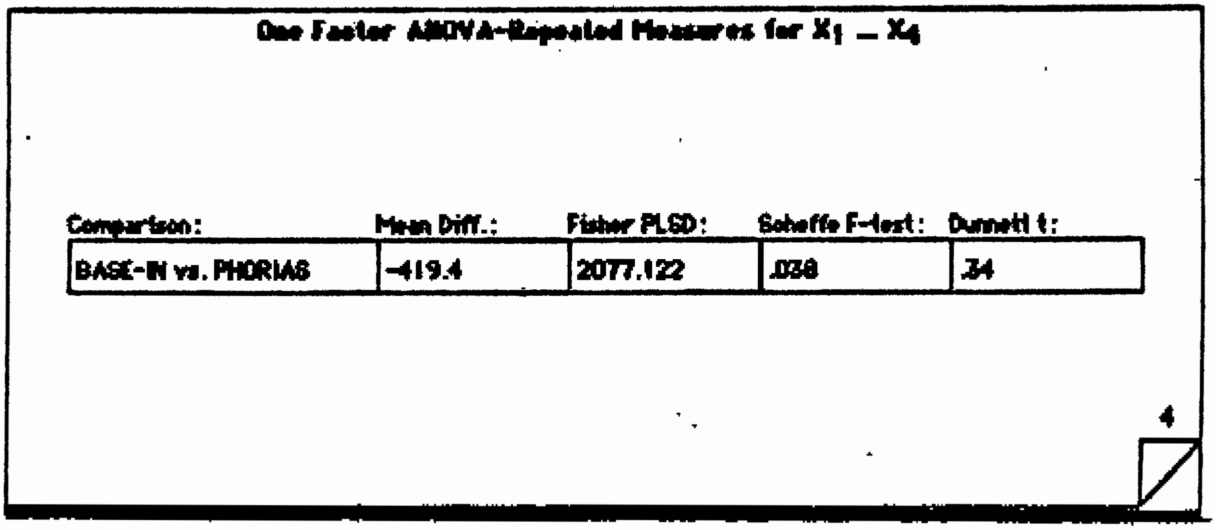
One Factor ANOVA-Repeated Measures for X_1 ... X_4

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
HABITUAL	15	14564.8	4265.601	1101.373
BASE-OUT	15	13012.667	4795.475	1238.186
BASE-IN	15	14186.4	5664.931	1462.679
PHORIAS	15	14605.8	7739.435	1998.313



One Factor ANOVA-Repeated Measures for X_1 ... X_4

Comparison:	Mean Diff.:	Fisher PLSD:	Scheffe F-test:	Dunnett t:
HABITUAL vs. BASE-OUT	1552.133	2077.122	.527	1.257
HABITUAL vs. BASE-IN	378.4	2077.122	.031	.306
HABITUAL vs. PHORIAS	-41	2077.122	3.6748E-4	.033
BASE-OUT vs. BASE-IN	-1173.733	2077.122	.301	.951
BASE-OUT vs. PHORIAS	-1593.133	2077.122	.555	1.29



One Factor ANOVA-Repeated Measures for X_1 — X_4

Comparison:	Mean Diff.:	Fisher PLSD:	Scheffe F-test:	Dunnett t:
BASE-IN vs. PHORIAS	-419.4	2077.122	.038	.34