HEAD AND EYE MOVEMENT PATTERNS DURING A PROOFREADING TASK

Optometry Senior Project

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INTRODUCTION

Recently there has been growing interest in developing progressive addition spectacle lenses that are the "best" at satisfying the needs of a large number of users (Pope). Most PAL-wearers are instructed to "lead with your chin" and otherwise alter their natural head, eye, and neck postures to utilize the lenses appropriately. It seems logical that a spectacle lens company would desire to produce a lens that would provide clear vision at all usual distances and directions of gaze while the user maintains his or her natural head, eye, and neck postures. Such a lens would be a clear advantage over those in existence today that require some training time before the lens can be fully effective.

The questions that necessarily need answers before any discussion of a new lens design can occur are these: Does a predictable head and eye movement pattern exist for a given person during common tasks? If so, is this pattern consistent across people with similar accommodative states (i.e. similar age groups)? If the answer to either of these queries is "No", then there is little reason to pursue design research that will produce a lens that will satisfy a person with one particular movement pattern. Each patient would require a custom-made lens that allows for his or her unique head and eye movement strategies. It goes without saying that this would be a prohibitively expensive endeavor.

Past research by Malinov et al. indicates that subjects prefer saccadic eye movements that are smaller than 15 degrees. Work by Lee suggests that people regularly combine head and eye movements. Studying the simultaneous use of the head and eyes gives a more accurate picture of a given person's visual habits. The present study was designed to measure head and eye movements during a particular proofreading task for a group of age-matched subjects, then to compare the results between and within subjects. The rationale for studying a reading task, rather than tasks at intermediate or far distances, is that conscious postural modifications while using a PAL occur most frequently during near tasks. This study is the first in a three-part research project to compare results across three different age groups.

METHOD

Subjects

The subjects were six students (5 female, 1 male) attending the Michigan College of Optometry. Each subject was between the ages of 20 and 29 with normal accommodative states. All subjects used single vision spectacles or contact lenses appropriate for the test distance when a correction was necessary. Beyond that, subjects used no optical device. They received no remuneration. All subjects read and signed a Human Subjects Consent form approved by the Michigan College of Optometry Human Subjects Committee.

Apparatus

Each subject sat below an overhead-affixed headpiece, which secured the head (Figs. 1 and 2). The headpiece allowed rotation around the vertical axis but restricted all other motion. An EOG apparatus monitored eye movements with a total of three recording electrodes: one placed at each lateral canthus and one on the left ear lobe. The headpiece was attached to a potentiometer. Both it and the EOG electrodes were connected to a computer. A data acquisition software package (LabVIEW) collected

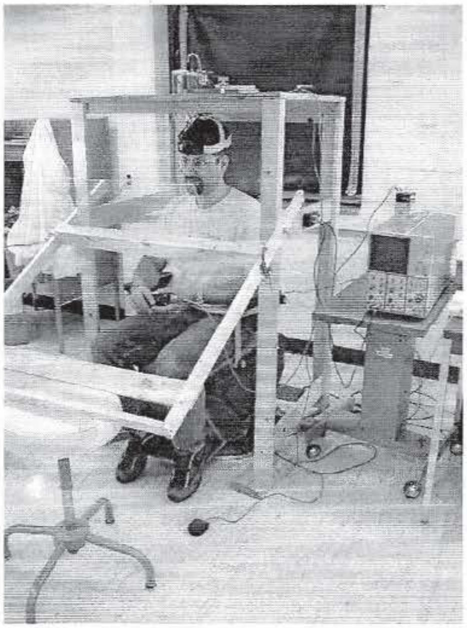

Figure 1

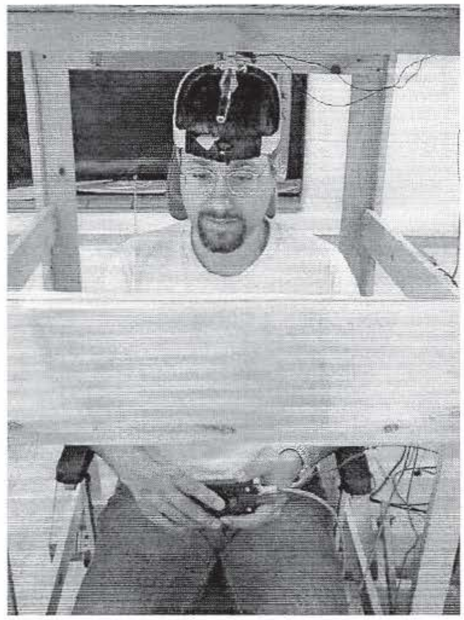

Figure 2

head and eye movement data in analog form and converted them to digital form. The subjects held a three-button keyboard device, also connected to the computer, which served as the system by which the subjects indicated their choices for each experimental condition (explained later).

Stimuli

The stimuli were a series of five 25 x 35 cm cards placed at a distance of 40 cm before and 30 degrees below the primary gaze position. Each card contained eleven three-letter clusters (triads) spaced 4 degrees apart, spanning horizontally from 20 degrees to the left to 20 degrees to the right of the straight-ahead position (Fig. 3). The letter size was equivalent to 20/40 letters on the Snellen scale. They were printed with black ink on a white background at 50% contrast. The letters selected were those taken from the Bailey-Lovie (Bailey) visual acuity measurement system. This visual acuity system was chosen because the relative difficulty of identifying each letter is

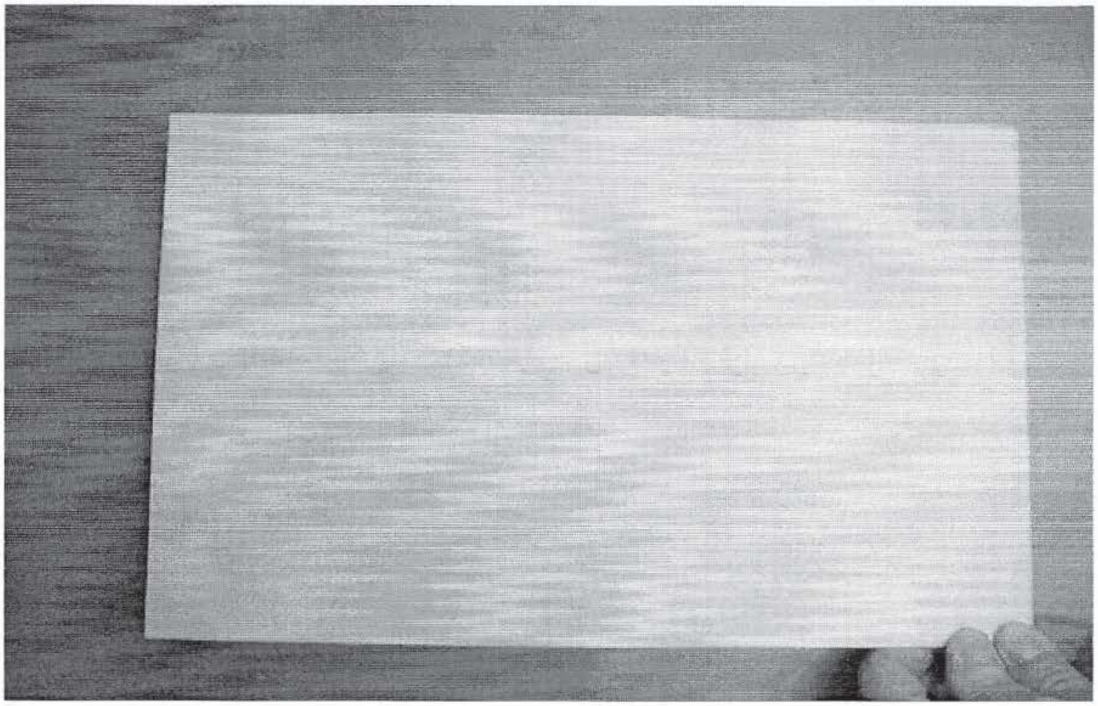

Figure 3

approximately the same.

Procedure

The triads were numbered from one to eleven, with the triad 20 degrees left of straight-ahead designated as "1", the straight-ahead triad as "6", and 20 degrees right of straight-ahead as "11". The operator manually moved a 25 x 71cm tagboard card with a 2.5 x 2.5 cm square cut out of the middle to expose the triads individually in a pre-determined pattern (Fig. 4). The subject looked at each triad as it was presented and determined which position (left, middle, or right) a target letter held within the triad. After determining the position, the subject pressed the button on the hand-held keyboard that indicated his or her choice.

Subjects were instructed to maintain head and eye posture while pressing the buttons. Completing the exposure and response series on one card constituted a "run".

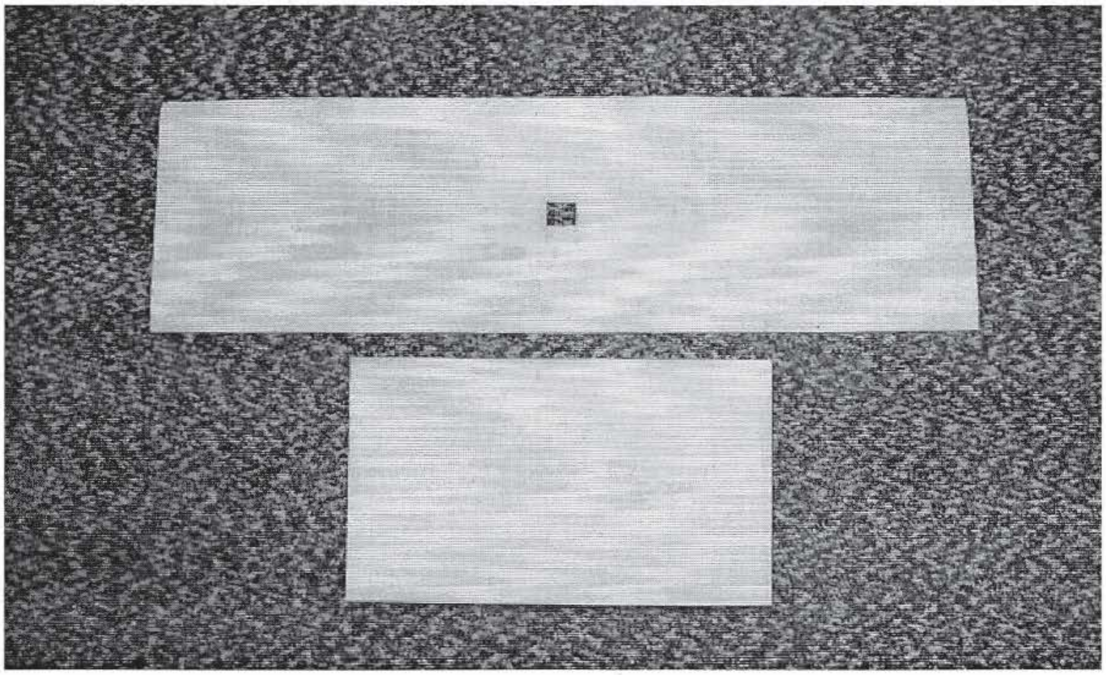

Figure 4

Several practice runs were conducted to acquaint the subject with the procedure. All five stimulus cards were utilized during one session. Each subject participated in three sessions, for a total of 15 runs. The target letter was the same for each triad on a single card but different for each of the five stimulus cards.

The operator exposed the triads in the following sequence: (6, 1, 11, 6) [5, 4, 3, 2, 1, 6, 7, 8, 9, 10, 11, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11] (6, 1, 11, 6). The triad positions in parentheses were for eye calibration, and no head movement was permitted. The bracketed triad positions correspond to the testing condition, in which the subject could use any combination of eye movement and horizontal head movement he or she desired in order to perform the task.

All data were collected by LabVIEW software at a rate of ten times per second.

Head and eye movements as well as keyboard selections were measured in analog volts, converted to digital form, and automatically saved to a Microsoft Excel spreadsheet. If the sum of the eye and head movements did not equal the stimulus at the observation points, either the subject did not accomplish the task or one or both of the recording devices was not operating properly. A run was rejected if the head and gaze read-out positions did not sum to within 3.5 degrees at 4 or more of the 22 stimulus positions.

RESULTS

We found a general pattern for the average subject: eye movement led head movement. In other words, the eyes did the work up to about 8 degrees from center, then the head started to move slowly in the direction of the eyes to about 8 degrees from center, then the eyes completed the task to the extreme 20 degree position. This was true regardless of whether the motion was leftward or rightward.

Subjects KR (Fig. 5) and TF (Fig. 6) had very similar patterns for accomplishing the task. Both used eye movements to 8 degrees from center, then also used head movements. Their patterns were symmetrical and consistent with the average pattern.

Subject ZB (Fig. 7) followed the average pattern in that eye movements prevailed until about 8 degrees, then head movement began up until it was 8 degrees from center, but the head movements were not as smooth as the other subjects' head movements.

Subject AB (Fig. 8) very consistently used almost entirely eye movements to complete the task for each run. For all effective purposes, this subject did not use head movement at all.

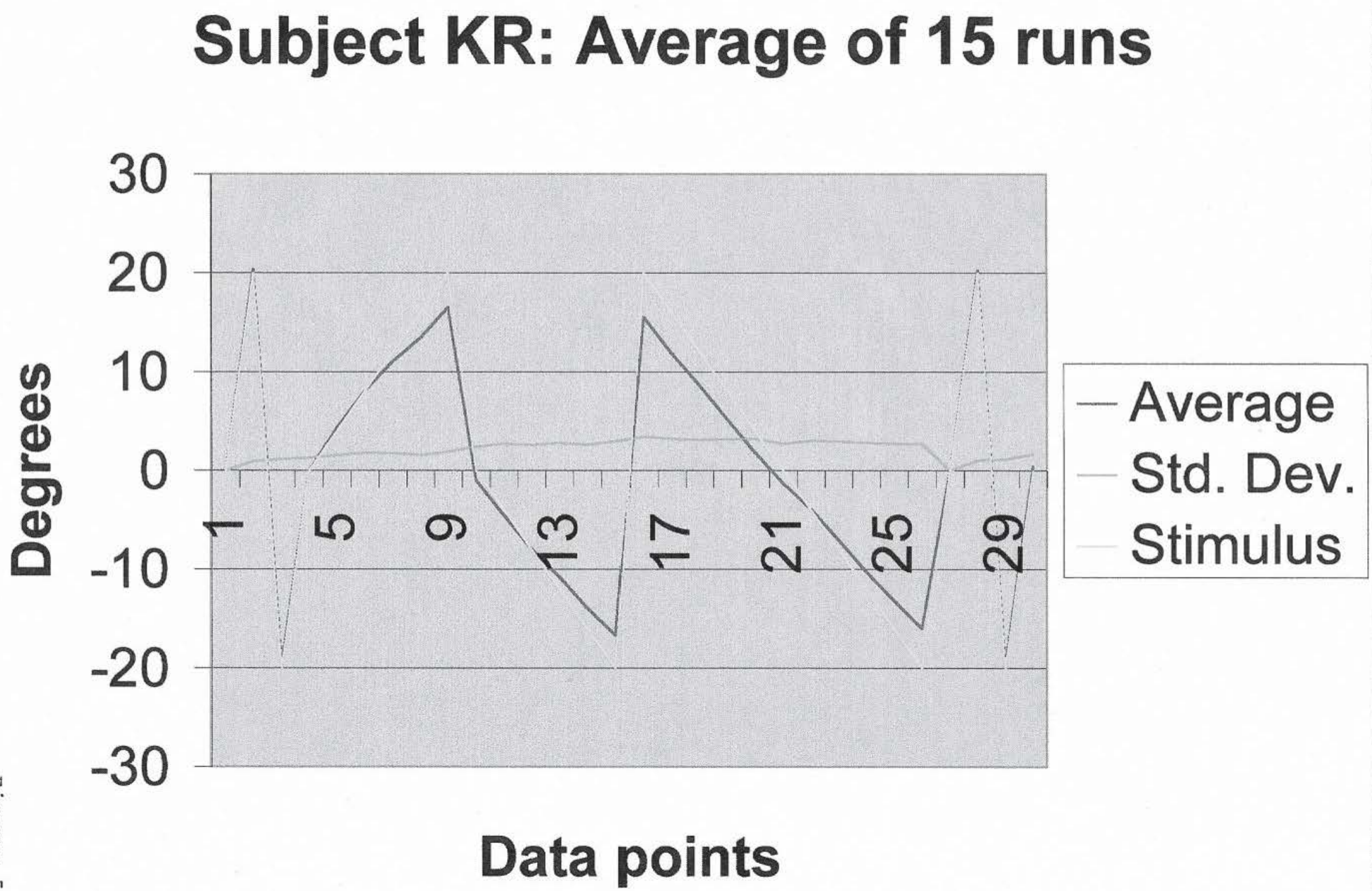
Subject KR: Average of 15 runs
Degrees
30
20
10
0
-10
-20
-30
1
5
9
13
17
21
25
29
Data points
Average
Std. Dev.
Stimulus

Figure 5

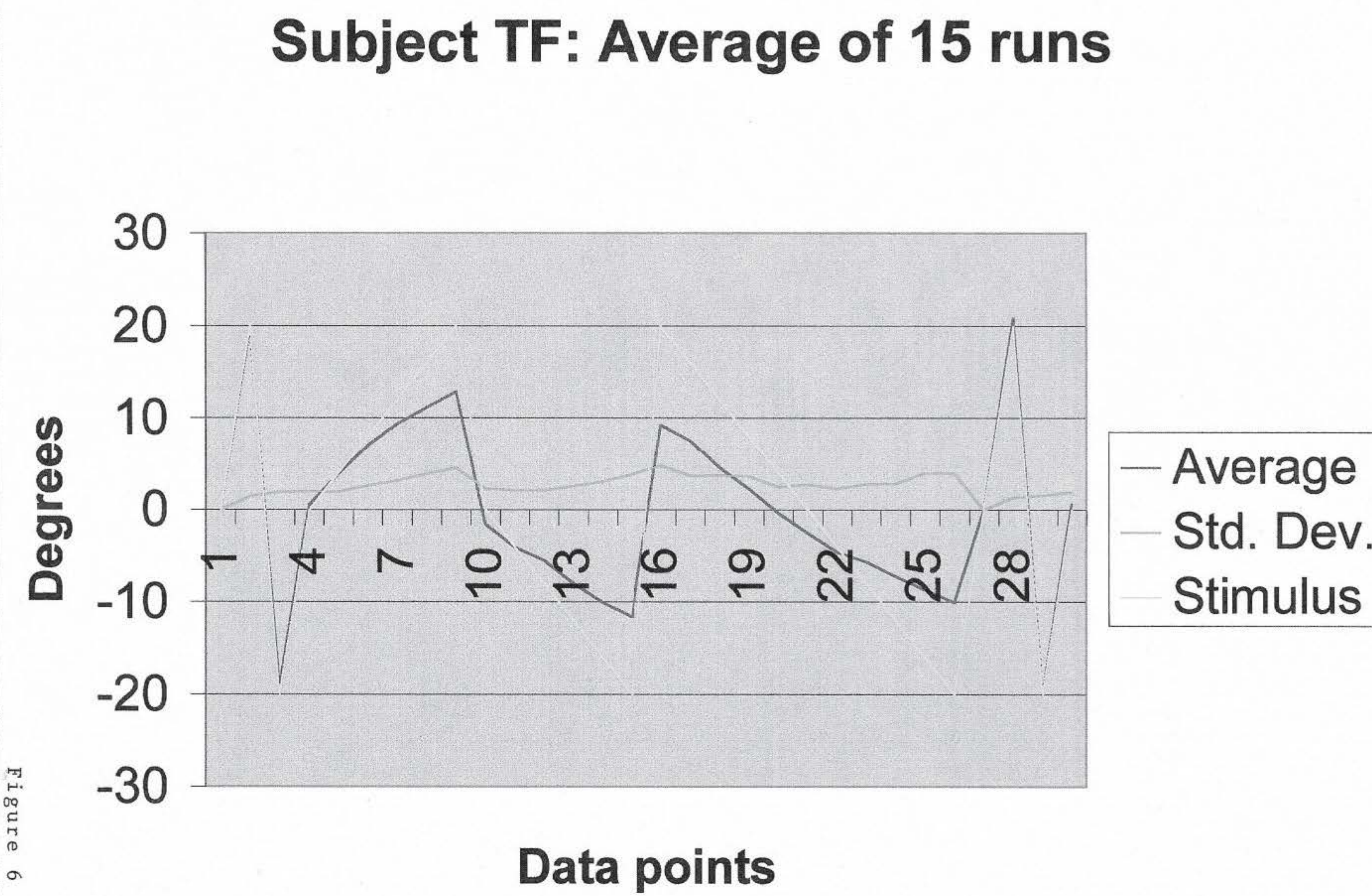
Subject TF: Average of 15 runs
Degrees
30
20
10
0
-10
-20
-30
1
4
7
10
13
16
19
22
25
28
Data points
Average
Std. Dev.
Stimulus

Figure 6

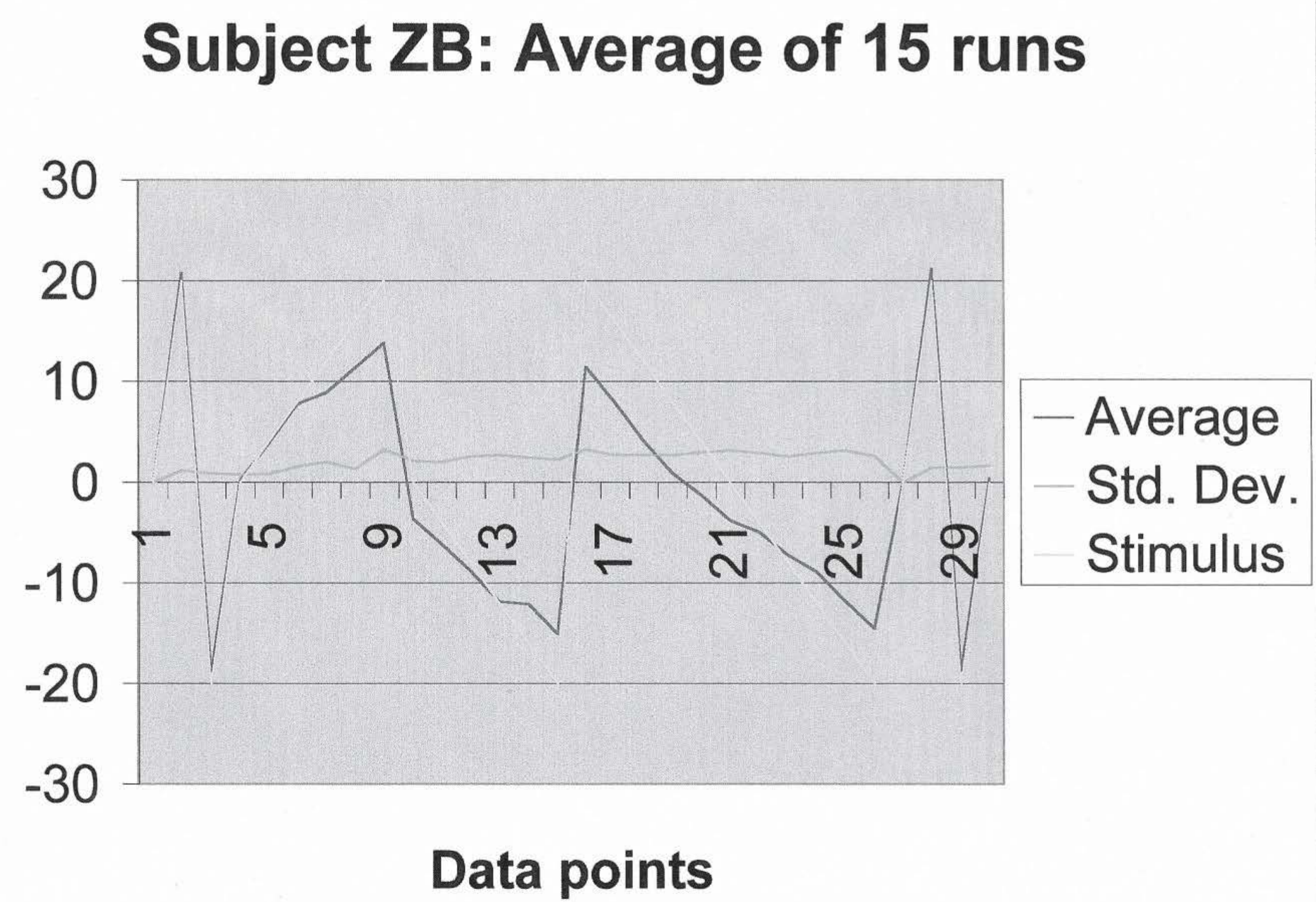
Subject ZB: Average of 15 runs
30
20
10
0
-10
-20
-30
Degrees
1
5
9
13
17
21
25
29
Data points
Average
Std. Dev.
Stimulus

Figure 7

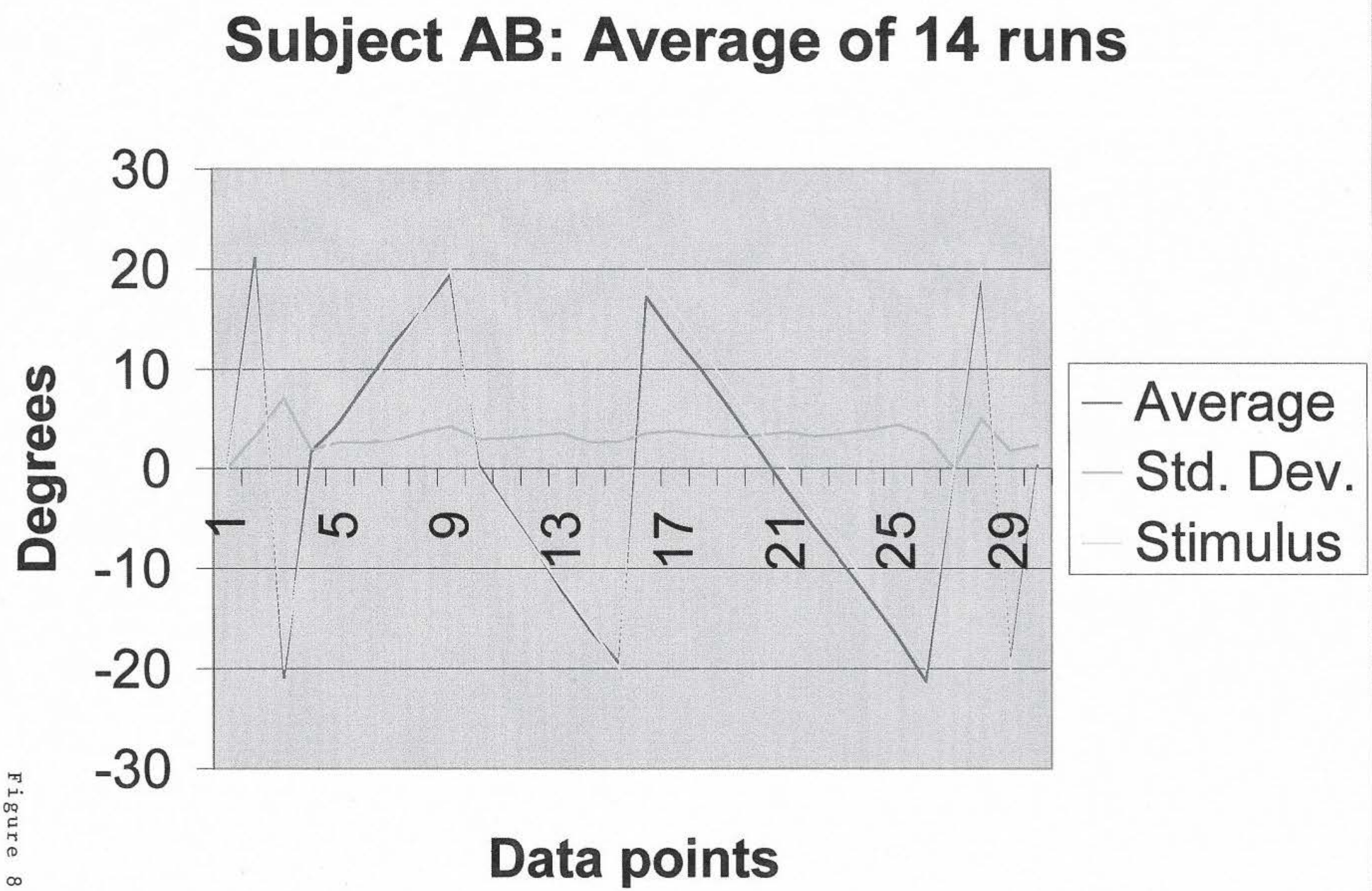
Subject AB: Average of 14 runs
Degrees
30
20
10
0
-10
-20
-30
1
5
9
13
17
21
25
29
Data points
Average
Std. Dev.
Stimulus

Figure 8

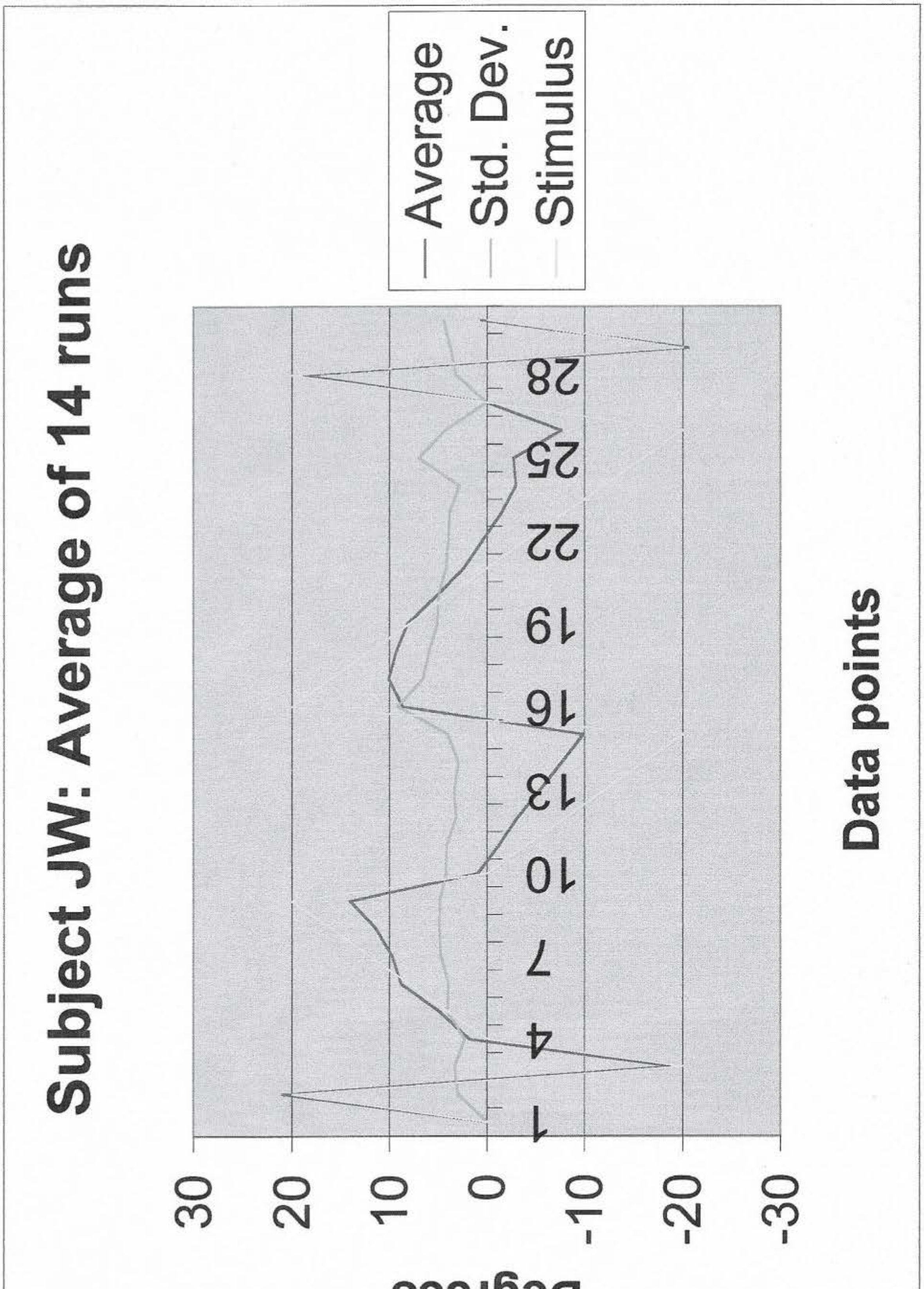
Subject JW: Average of 14 runs
Average
Std. Dev.
Stimulus
Degrees
30
20
10
0
-10
-20
-30
1
4
7
10
13
16
19
22
25
28
Data points

Figure 9

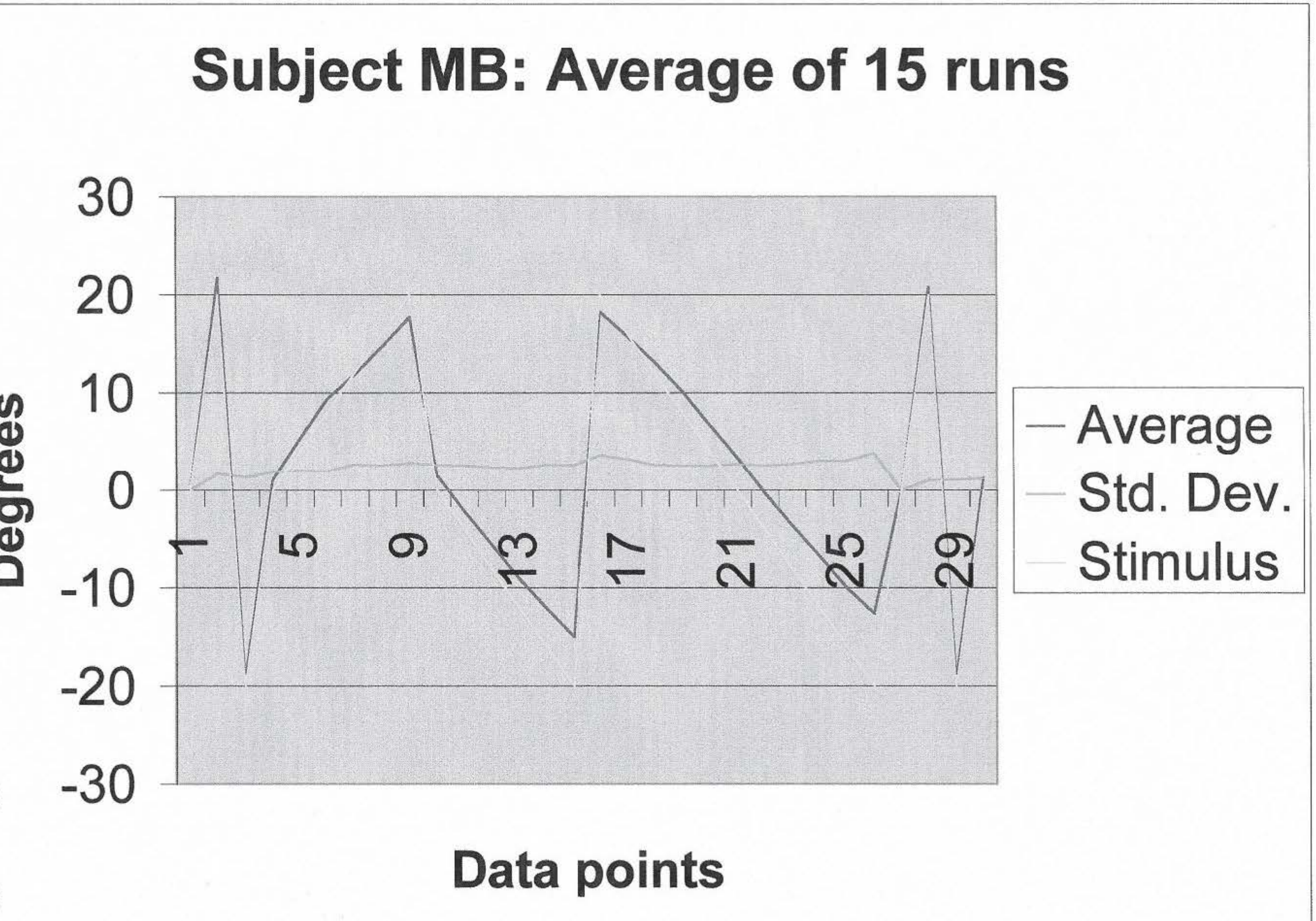
Subject MB: Average of 15 runs
Degrees
30
20
10
0
-10
-20
-30
1
5
9
13
17
21
25
29
Data points
Average
Std. Dev.
Stimulus

Figure 10

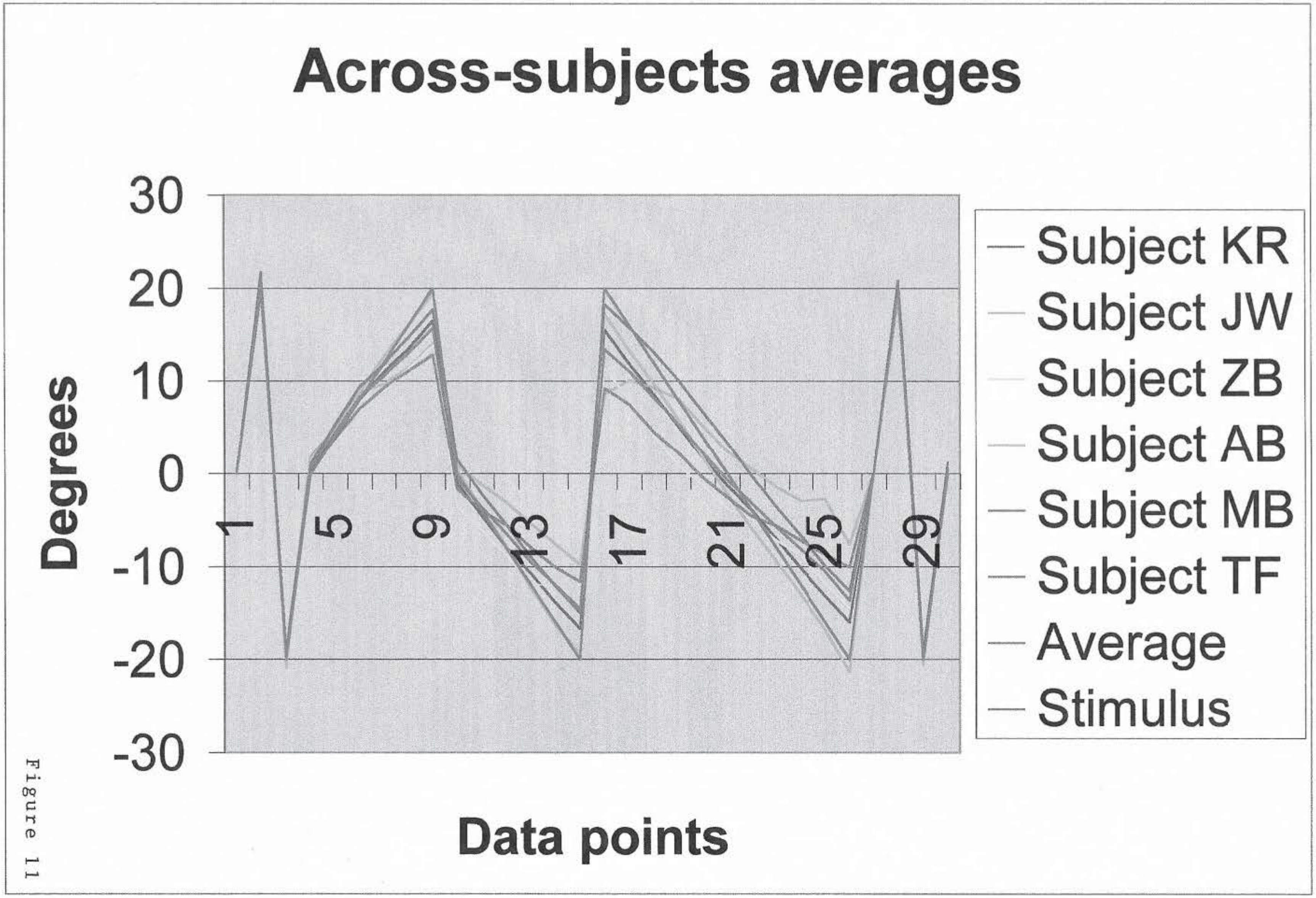
Across-subjects averages
30
20
10
0
-10
-20
-30
Degrees
1
5
9
13
17
21
25
29
Data points
Subject KR
Subject JW
Subject ZB
Subject AB
Subject MB
Subject TF
Average
Stimulus

Figure 11

Subject JW (Fig. 9) used eye movements to about 8 degrees when moving left, but used mostly head movements when moving to the right. Overall, this subject used more head movement than eye movement for the entire task. This subject's pattern could be described as the "opposite" of AB's pattern.

Subject MB (Fig. 10) had a different strategy for moving right than for moving left. Left movement was accomplished almost entirely with the eyes; however, right movement was completed with a combination of eye and head movements. Again, the head moved to a maximum of about 8 degrees from center. All individual averages can be seen together as one graph in Figure 11.

Another strategy for analyzing the data is to determine what percentage of the total movement was due to eye movement when moving left or moving right. Results of this analysis are as follows:

	Left	Right	Symmetrical?
Subject KR	80	80	Yes
Subject TF	60	55	Yes
Subject ZB	65	65	Yes
Subject AB	100	100	Yes
Subject JW	60	45	No
Subject MB	90	70	No

DISCUSSION

For all subjects, the majority of the total movement was accomplished using the eyes, with the head contributing a maximum of 8 degrees. This was true regardless of whether the target was to the left or to the right of central fixation. A pattern emerged, although not a strong one, in which the eye-movement-to-total-movement ratio ranged from 60-100% for left of center (mean of 75.8%) and from 45-100% (mean of 54.1%) for right of center. In other words, there seemed to be a slight, though not statistically significant [paired Student's t test], tendency for more head movement when moving to the right than when moving to the left. Why the difference? 1. Perhaps the particular order of triad presentation biased the results. 2. Perhaps reading habits caused the difference. All subjects are native English speakers and are accustomed to reading from left to right. This requires a series of saccades moving rightward. During the first five data points of each test condition, subjects utilized a series of saccades moving toward the left. With the notable exception of AB, each subject used only eye movement until reaching 8 degrees left of center, then added head motion. When moving rightward, these subjects used some combination of head and eye movement. It could be that when performing the familiar task of reading from left to right, the most efficient strategy is to use both head and eye movements. Since left-bound saccades are not common, a different strategy was used to accomplish them. It would be interesting to repeat this experiment with subjects who read from right to left to determine whether the strategy is reversed.

Differences between subjects include:

-Jerky movements vs. smooth movements. All subjects used smooth head and eye movements except for AB, who used essentially no head movements, and ZB, who used jerky head movements.

-Symmetry of eye-movement-to-total-movement ratio.

-Using one pattern consistently for each run vs. using different patterns each time. The standard deviations for most subjects were very consistent for each data point, indicating that the subjects used a similar strategy for each run. JW, however, had a variable standard deviation at each data point, suggesting that this subject used different combinations of head and eye movements for each run.

As stated before, most subjects chose the same strategy each time the test conditions occurred. This was not true for JW and, therefore, cannot be considered a generalization. The conclusion here is that most people will follow a habitual strategy when performing a familiar near task, but there are those who will choose to vary the pattern each time a particular task is encountered.

How do these observations reflect on a presbyopic person using a PAL? It is well known that a PAL's channel width is limited, hence the instructions to "lead with your chin". Someone who is accustomed to using primarily eye movements, such as AB, will likely not be as comfortable when initially faced with this lens type. The same may be true, although perhaps not to the same extent, in those such as JW that utilize several different strategies when repeatedly accomplishing the same goal. Those who habitually use both head and eye movements would be the best candidates for initial comfort and adaptation to a PAL.

An interesting fact is that a "standard" PAL design extends as much as 14 degrees to each side of the near zone's center (Cho and Benjamin). According to the eye movements measured in the present experiment, the maximum eye movement required in either direction is only 12 degrees, which agrees with the previously cited research performed by Malinov et al. Assuming that the subjects of this experiment are representative of the entire population, why do first-time PAL users require an adaptation time in which they need to learn to use the lenses? If the zone were adequate, no adaptation would be necessary with respect to the clear zone of near vision (it may still be necessary to adapt to peripheral "swim"). The truth of the matter is that human beings are dynamic creatures faced with a multiplicity of different spatial relationships in which they must perform throughout a typical day. Although the data suggest that the near zone width is adequate for a person's needs, this experiment was conducted in a controlled, unnatural environment at one working distance with a fixed horizontal span of targets. It is unlikely that these conditions exemplify an entire population's near visual needs.

In conclusion, the present experiment demonstrated that most subjects follow a measurable pattern when repeatedly placed in a certain situation (much like a work or home office environment). With only one exception (JW), there was little variation in strategy when the same person faced the same conditions. However, the patterns across individual subjects were noticeably varied. Even though this study's conditions were controlled and unnatural, it would be reasonable to assume that people in "real-life" situations would develop a strategy that would differ from other individuals' habits. To presume that one could design a progressive addition lens that would accommodate the behavior of a great number of people, therefore, seems quite farfetched. Although there is great marketing value in offering a lens that allows for "natural" head and eye movements, the results of this study indicate that one lens could not fit all.

References

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