Shortening of feet in longer articulatory units

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ASA Abstract

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A twenty-minute radio broadcast of a short story, digitised and measured for both syllable and pause durations. was studied with respect to the durational characteristics of both pause durations and rhythmic groups. Syllables were grouped into feet and foot durations calculated. Feet were then grouped into inter-pausal units and the durations of these larger articulation groups also calculated. The hypothesis that pause duration is a function of average foot length, determined over the previous n feet, was tested for different values of n but no supporting evidence was found. It has already been shown that the durations of both stressed and unstressed syllables in a foot tends to decrease as the number of syllables in the foot increases. Evidence was found here for a similar shortening of average foot durations as the number of feet per inter-pausal unit increases. This shortening indicates that an element of planning may be involved at higher articulatory levels. That the shortening is asymptotic lends support to the concept of a minimum duration at some level of the timing hierarchy.

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1 Introduction: foot length and duration

A twenty-minute radio broadcast of a short-story, digitised and measured for both syllable and pause durations, was studied with respect to the relationship of pause durations to stress groups.

A phonemic transcription of the broadcast was prosodically tagged by two professional phoneticians for stress, intonation and prosodic boundaries at the phrase and clause level. These tags were used to identify stressed syllables, which were then grouped into feet such that every foot either contained only phrase- or clause-initial unstressed syllables, or started with a stressed syllable and included all following unstressed syllables up to the next prosodic event, which was defined as either a stressed syllable or a phrase or clause boundary, as indicated by the prosodic transcription. Durations of these feet were recorded, along with the number of syllables and phonemic segments they included.

Pauses were defined as any measurable silence in the acoustic signal that occurred between valid syllables. Durations ranged from 72 ms to 2363 ms, with quantiles at 433 ms, 743 ms, and 1171 ms. Pauses containing breathy noise were distinguished, but not treated separately in the experiments.

Feet were further grouped into interpausal units (runs) that varied in length from 0.2 seconds to 7.1 seconds, with a median of 1.9 seconds. Figure 1 shows the distribution of the pause lengths; figure 2, foot lengths, and figure 3, run lengths. Figures 4, and 5 show distributions of stressed and unstressed syllable durations in the passage. Mean durations for these syllables were 223 and 151 milliseconds respectively.

Boxplots were produced using the Splus statistical package (figure 6) to show that as the number of syllables in the foot increases, the mean length of the foot decreases. In this and the following figure, the width of each box is proportional to the log of the number of samples in each category, and the horizontal lines mark the 25th, 50th and 75th quantiles of the data. Whiskers are drawn to 1.5 times the interquartile range, and notches in the boxes indicate significance at the 5% level if they show no overlap.

However, this simple statistic ignores the almost two-fold difference in duration between stressed and unstressed syllables. To factor this out, further plots (figure 7) were produced to show the two types separately. It is clear from this figure that both stressed and unstressed syllables show a similar trend, shortening as foot length increases.

Figure 8 shows that amongst the unstressed syllables, those in phrase- or clause-initial position with no leading stressed syllable are considerably shorter than equivalent ones following a stressed syllable in the foot, and that the unstressed syllables in solo position are significantly longer than those in feet of length three or more. It would appear from these data that there is compensation taking place in the articulation of both stressed and unstressed syllables that serves to bring stressed syllables into more of a rhythmic sequence.

2 Pause duration and foot length

To check whether pause duration could be shown to be a function of foot length, and therefore to contribute to this rhythmicity, foot durations were averaged over the previous 1, 3, 5, and all, feet in the run. Figure 9 shows scatterplots of pause duration against average length of the previous n feet. Regression lines show that there is almost no corelation between the two data sets. The steepest slope, that of pause duration against the previous single foot duration shows a correlation of only 0.109.

Since pause duration (shown in figure 1) is not normally but bimodally distributed, it may be the case that longer pauses can be better described as integer multiples of a shorter pauses. On this assumption, pause durations were examined modulo 750 milliseconds. taking the mean foot duration of 375 milliseconds as the center duration of a notional standard length pause and folding any pauses longer than 750 ms so that all multiples would be reduced to within the observed range for foot durations. Figure 10 shows that no increase in fit is gained by this operation; the regression lines are almost completely flat, indicating a lack of any correlation.

The above is not sufficient evidence to discount a relationship between foot length and pause duration, but it does perhaps indicate that other factors may be involved if indeed such a relationship exists.

3 Foot duration and run length

The converse of pause length is run length; the length of time between pauses. This is presumably a function of the number of syllables in the run, but it can be shown that there is also a correlation between the lengths of the feet made up of those syllables and the number of feet in the run.

Figure 11 shows that as run length increases; i.e. as there are more feet in the interpausal unit, the mean duration of the feet in that utterance decreases. The correlation is weak, at 0.25, but that there is an effect at all indicates that there may be some articulatory planning of the utterance at levels higher than those just required for rhythmic considerations alone. Regression coefficients for the fit shown here are 420 ms minus 6.2 times the number of feet in the run.

4 Conclusion

It has been demonstrated that syllable duration is affected by the rhythmic structuring of the utterance, by showing that durations of both stressed and unstressed syllables decrease as the number of syllables in the foot increases. This has the effect of normalising the distance in time between stressed syllables and preserving the rhythmicity of the utterance.

The hypothesis that there might be a correlation between this rhythmic structuring and the durations of the pauses between the utterances was tested by examining pause durations as a factor of the average duration of the n preceeding feet, where n was 1, i.e. the immediately prepausal syllable, 3 and 5, representing windows averaging further back into the utterance, and 'all', taking the average foot duration across the utterance as a whole. In none of these cases could an effect be found.

It was shown, however, that there is a reduction in foot duration similar to that undergone by the syllables in feet, as the number of feet in the interpausal run increases. It is suggested that this might indicate a higher level of articulatory organisation, with some element of preplanning of the whole run prior to articulation.

figure 1: pause lengths

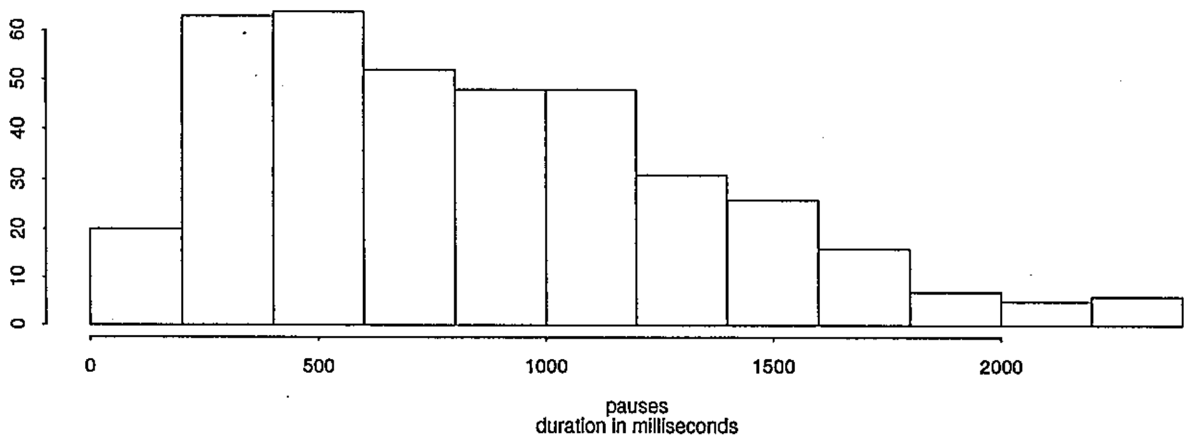


figure 2: foot lengths

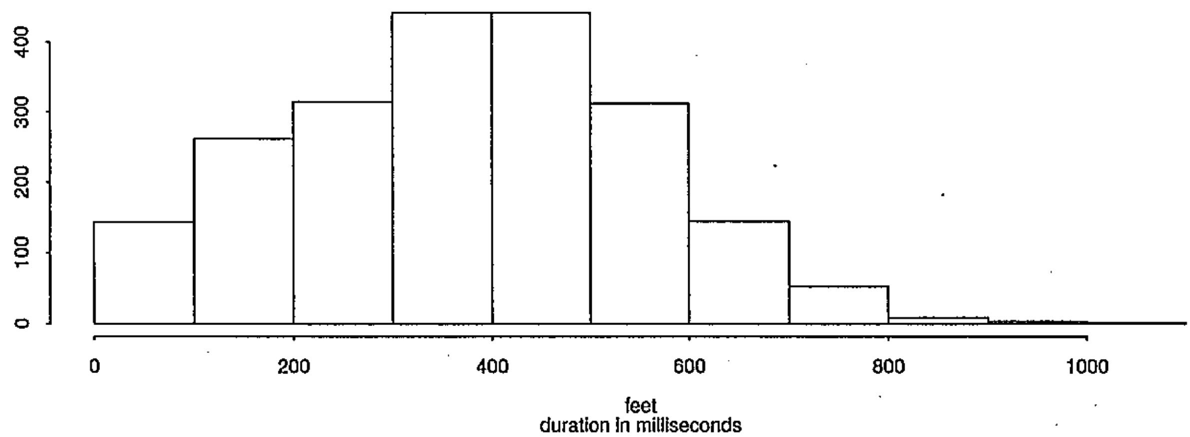


figure 3: run lengths

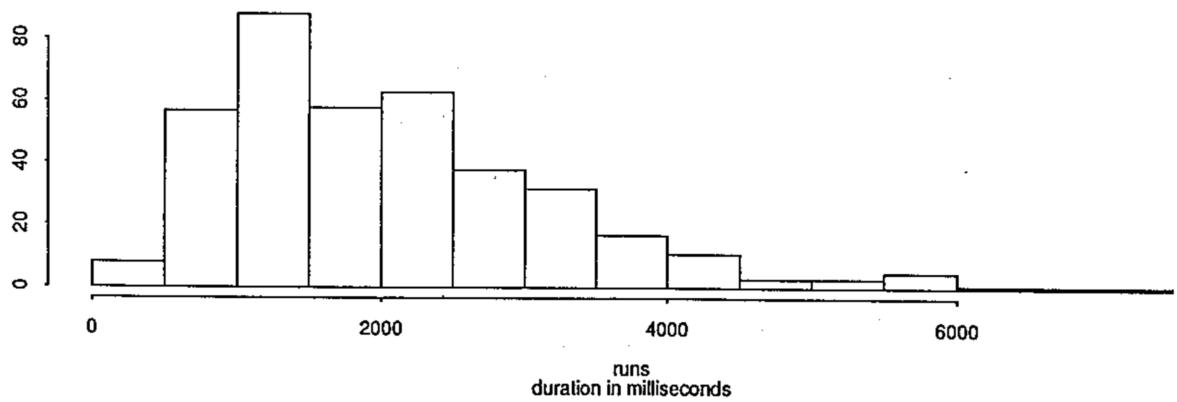


figure 4: stressed syllable lengths

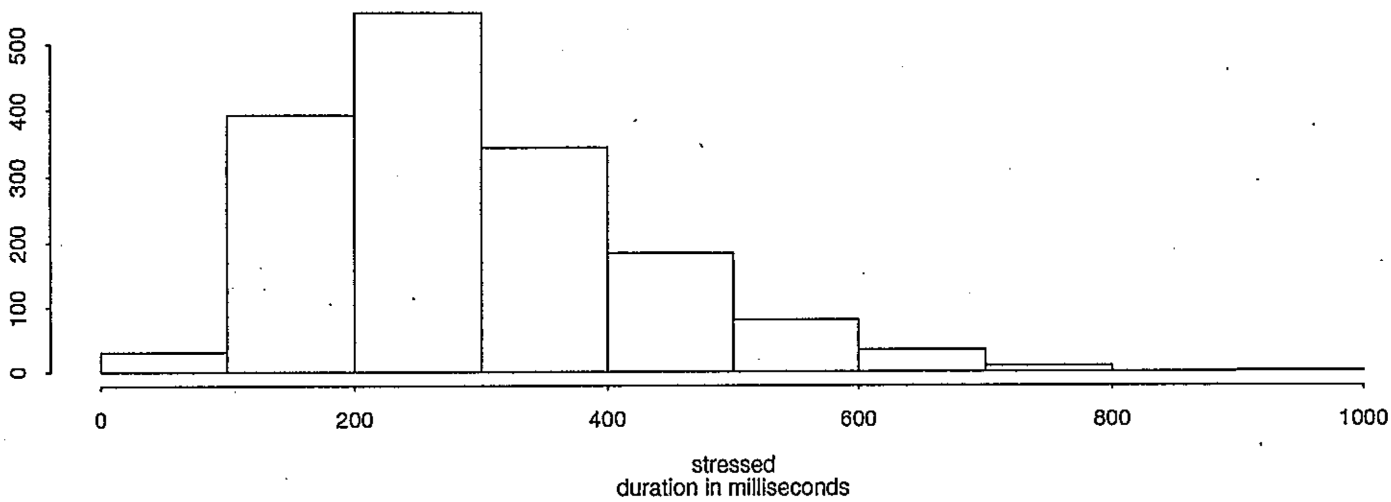


figure 5: unstressed syllable lengths

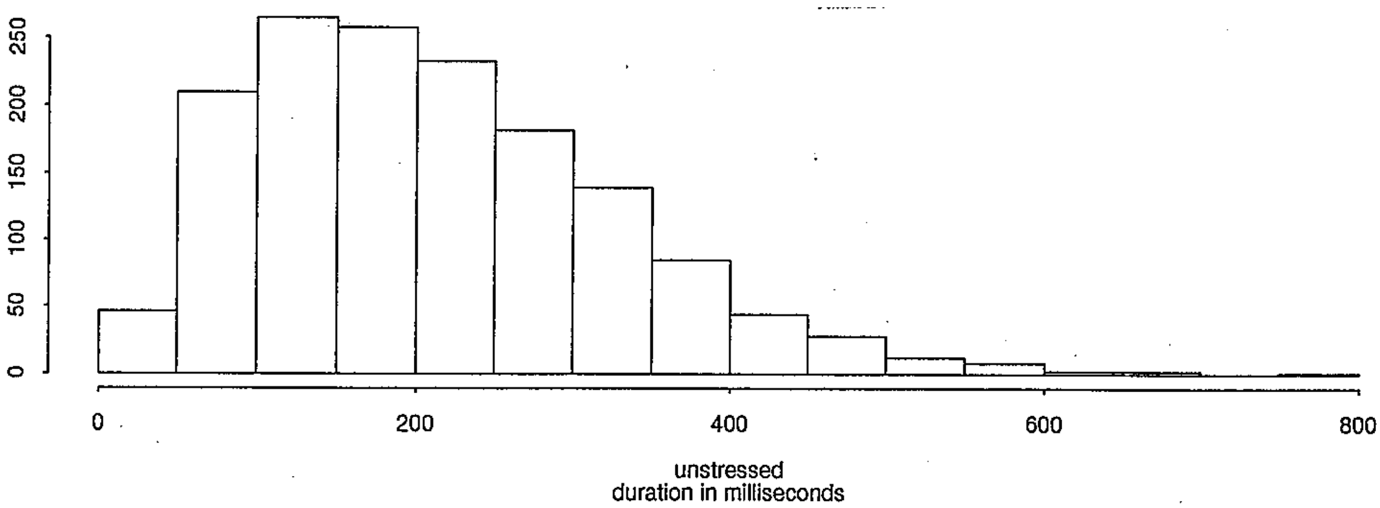
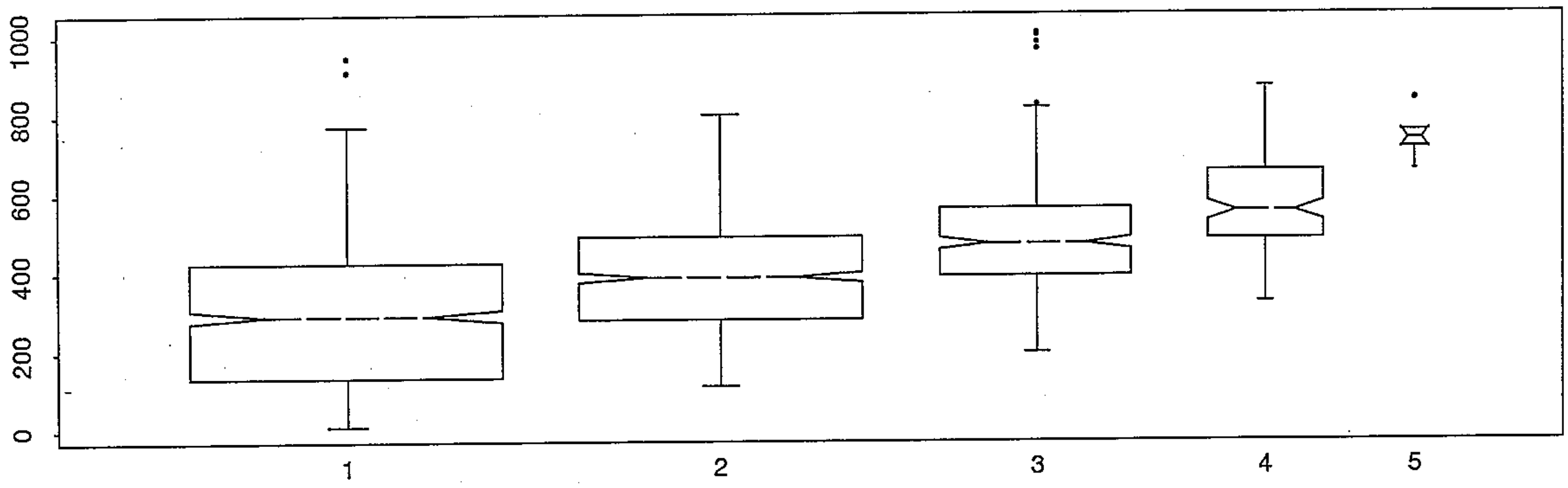


figure 6: foot durations by length in number of syllables



mean foot durations by length in number of syllables

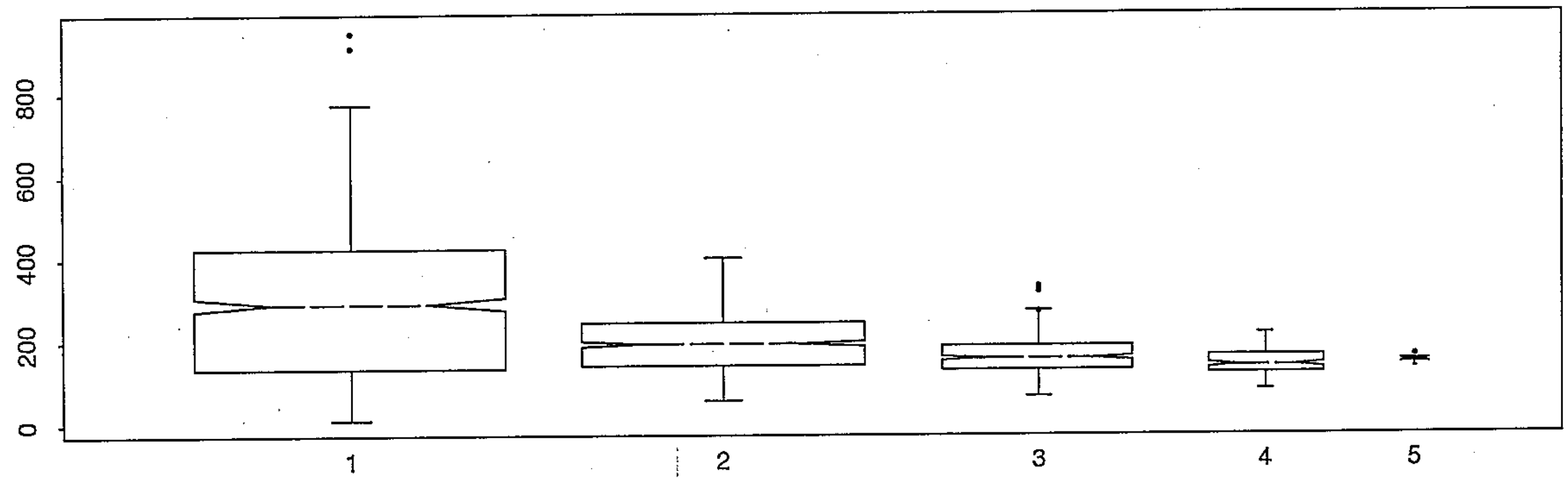
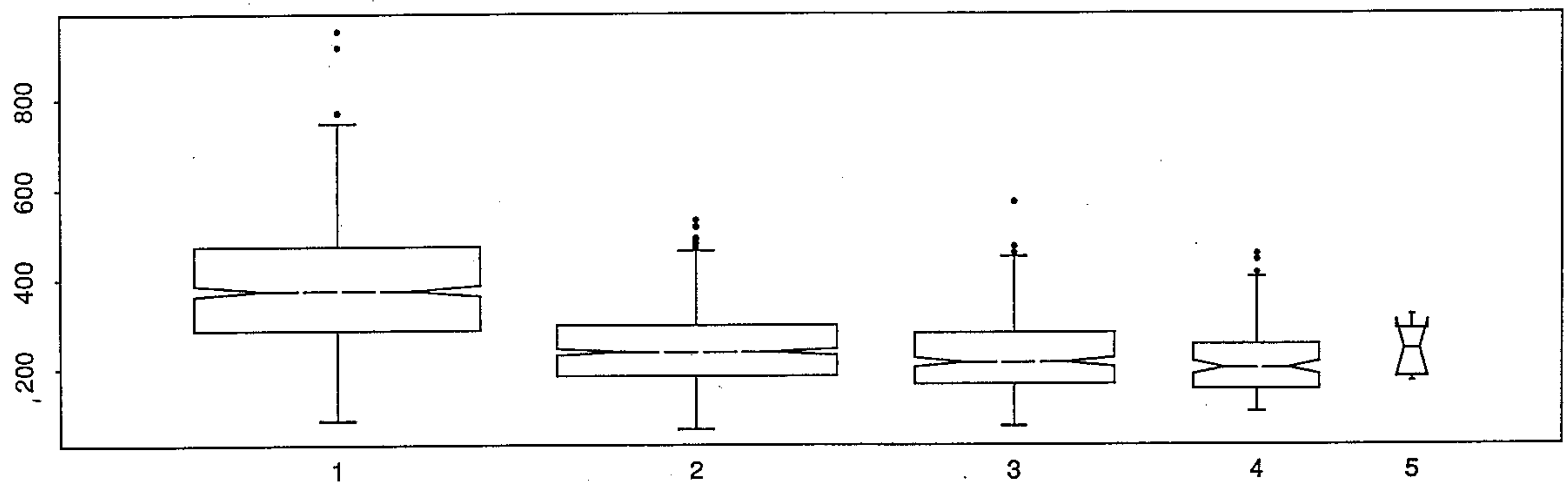


figure 7: stressed syllable duration by length of foot



mean unstressed syllable duration by length of foot

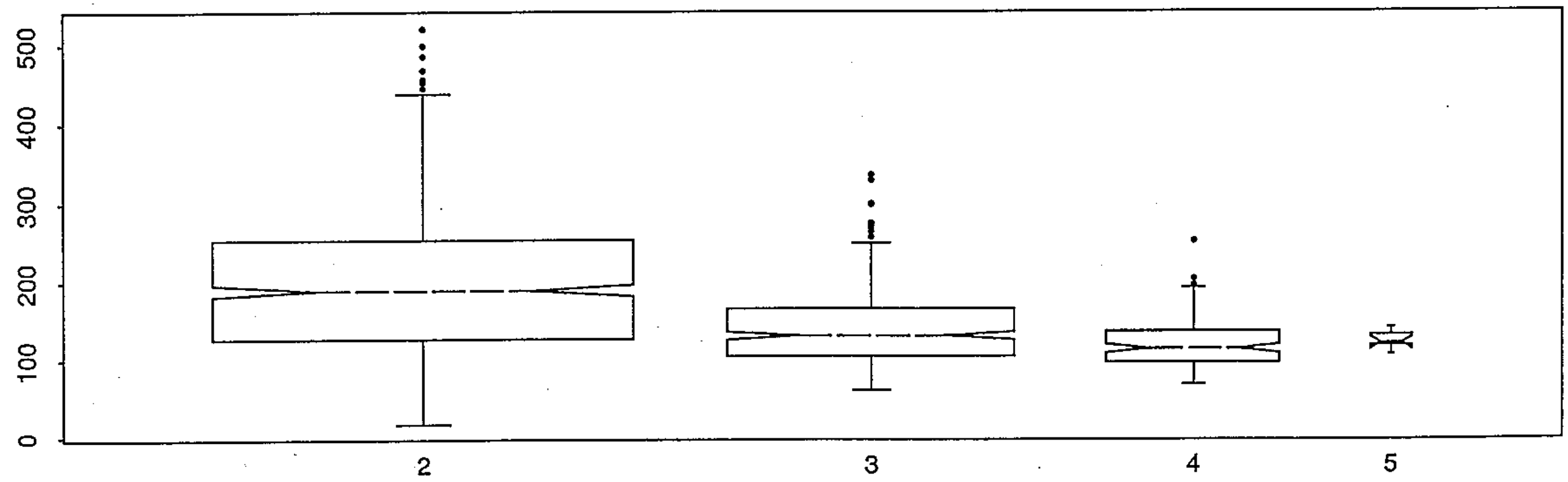


figure 8: unstressed syllable durations by length of foot

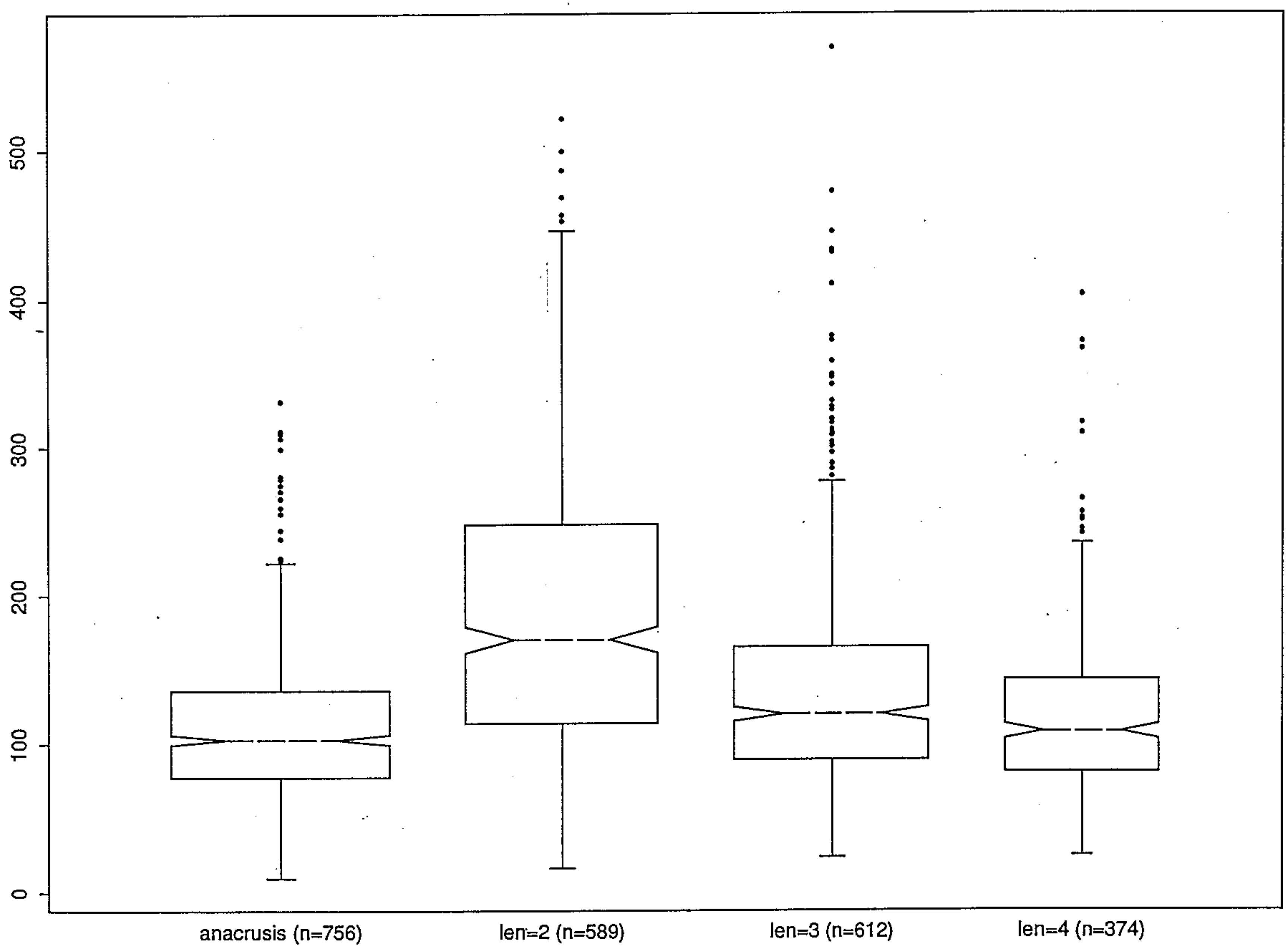


figure 9: pause length by averaged foot lengths

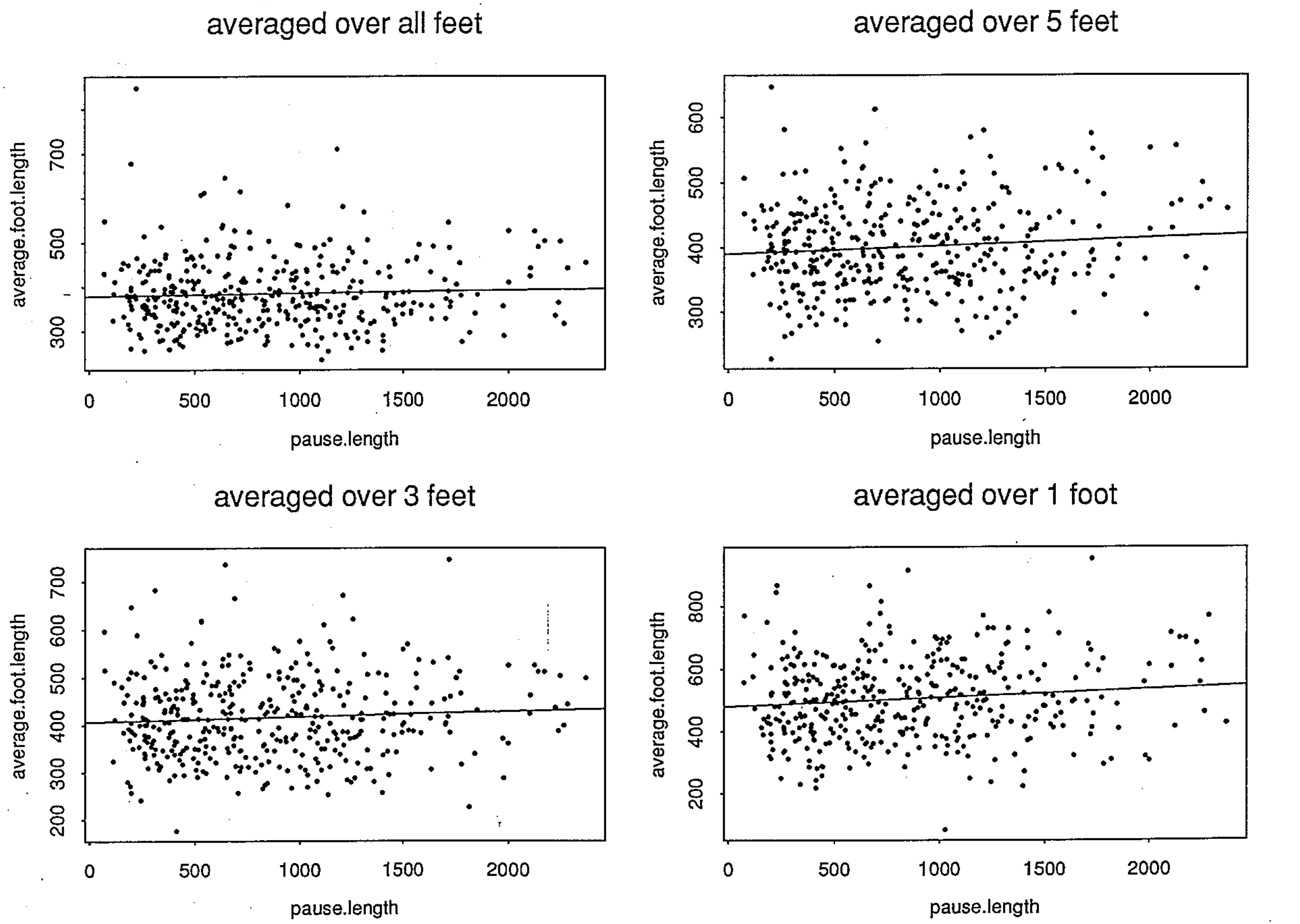


figure 10: pause length modulo 750

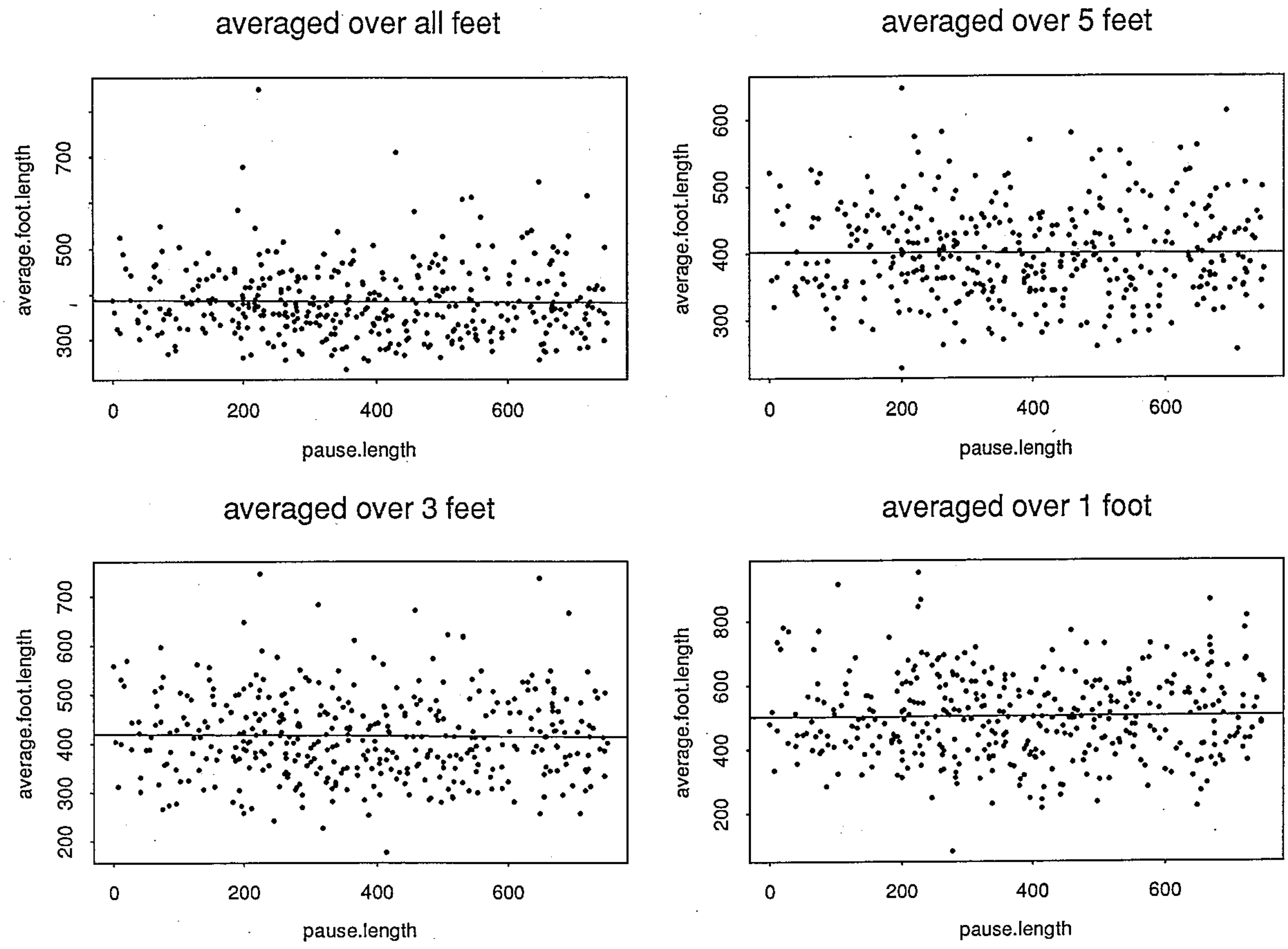


figure 11: mean foot length by run length