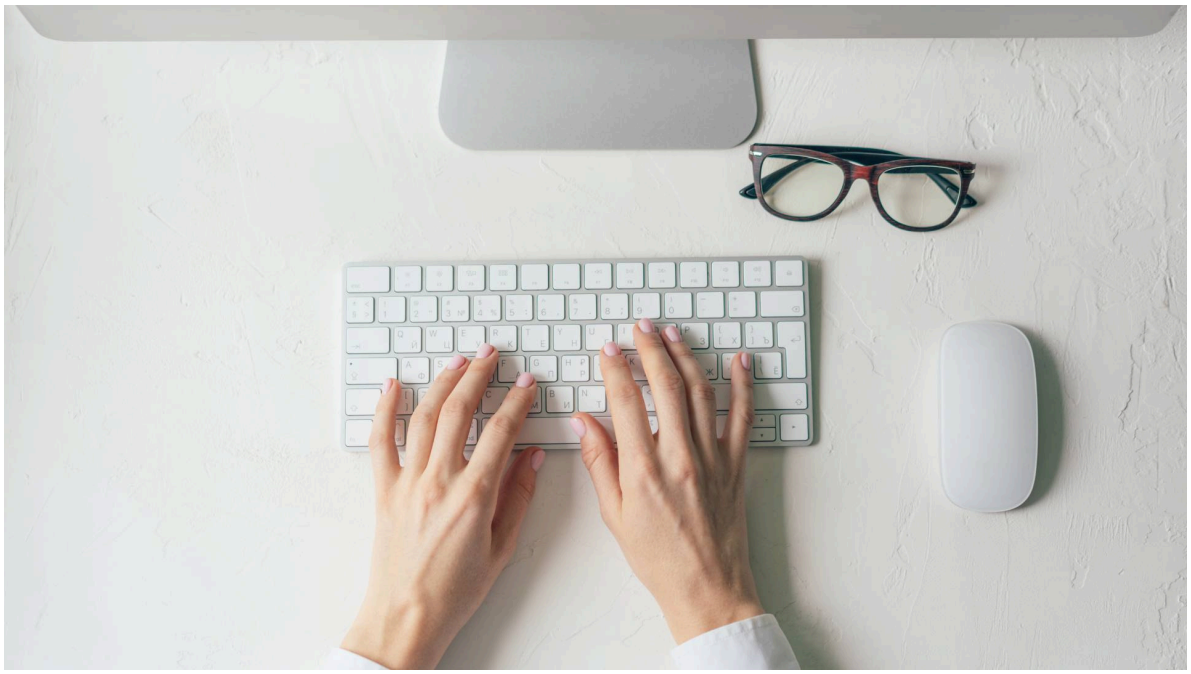
STAT 530 Experimental Design and Analysis

Professor Tianni Zhou

Effects of Font Size, Text Length, and Screen Brightness on Typing Speed

Incomplete Blocking in 2^3 Factorial Design



Created by
Marian Lu & Noppakan Sirikul
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Abstract

The objective of this experiment is to study how different factors affect typing speed using an Incomplete Blocking in 2^3 Factorial Design. The factors being evaluated are font size, text length, and screen brightness. The runs were carried out by the same person, on the same device, and in the same environment. Typing speed was evaluated by words per minute (WPM). We analyzed the data from the experiment using an Analysis of Variance (ANOVA) table. The findings indicate that none of the main effects nor interaction effects were significant. These results help with analyzing the role of accessibility settings across different interfaces and devices, and how they impact personal performance and productivity.

Introduction

Typing is a fundamental skill in the modern world, shaping how individuals interact with technology in both personal and professional contexts. From composing emails and writing reports to engaging in online communication, the efficiency and speed of typing directly impact productivity and user experience. As the prevalence of digital devices continues to grow, optimizing the conditions under which typing occurs has become increasingly important.

We measured typing speed using the typing test site Monkey Type, which returns metrics including WPM, accuracy, and consistency. We will be using WPM to evaluate typing speed. Monkey Type's typing tests are highly customizable, with adjustments including font size, length of the test, and types of words. For our experiment, we are interested in the following factors:

- **Font Size:** Adjustable font size is an accessibility feature that caters to people with a wide range of visual impairments and age groups. People with poor vision and/or older people seem to prefer larger font sizes for easier reading. We are curious to see if the size of the text on the screen affects typing speed. We are testing the effects on two different levels: low (size 2) and high (size 5).
- **Text Length:** Text length refers to the length of the typing test. Longer tests may give time for the subject to warm up, and accelerate in speed towards the end of the test. However, it requires a longer window of focus, so the subject may also experience slight fatigue towards the end of the test, possibly resulting in a decline in speed and even accuracy. We are testing the effects on two different levels: low (25 words) and high (50 words).
- **Screen Brightness:** Screen brightness is an important factor when evaluating typing speed because it directly affects visual comfort and focus. Poor brightness settings can also lead to glare or difficulty perceiving contrasts, further disrupting the user's ability to type efficiently. We are testing the effects of screen brightness on two different levels: low (50% brightness) and high (100% brightness).

Methods

Limitations and Assumptions:

The study assumes that the error terms are normally distributed and that all the observations are independent. It is important to note that for our experiment, we only performed one replicate. Lack of replication in factorial design experiments can potentially cause problems in statistical testing. Replicates provide us with an internal estimate of error, but without replicates, fitting the full model results in zero degrees of freedom for the error term. Our solution to this problem is pooling higher-order interactions to the error term.

Incomplete blocking means that all of the treatment combinations are unable to be treated in the same block. As a result, we must have confounding as well. We can choose to design the experiment in either two or four blocks. We chose two blocks because it allows us to clearly estimate the main effects as well as the two-order interaction effects and the highest order interaction effect would be confounded.

Model Configuration:

The Incomplete Blocking in 2^3 Factorial Design linear model:

$$y_{ijk} = \mu + \tau_i + \beta_j + \gamma_k + (\tau\beta)_{ij} + (\tau\gamma)_{ik} + (\beta\gamma)_{jk} + (\tau\beta\gamma)_{ijk} + \epsilon_{ijk}$$

where

y_{ijk} = observation at level i of factor A, level j of factor B, and level k of factor C

μ = grand mean

τ_i = main effect of factor A at level i ($i = 1, +1$)

β_j = main effect of factor B at level j ($j = 1, +1$)

γ_k = main effect of factor C at level k ($k = 1, +1$)

$(\tau\beta)_{ij}$ = interaction effect between τ_i and β_j

$(\tau\gamma)_{ik}$ = interaction effect between τ_i and γ_k

$(\beta\gamma)_{jk}$ = interaction effect between β_j and γ_k

$(\tau\beta\gamma)_{ijk}$ = interaction effect between τ_i , β_j , and γ_k (block effect)

ϵ_{ijk} = error term, where $\epsilon_{ijk} \sim iid\ N(0,\ \sigma^2)$

We also apply the following constraints to the parameters of our model:

$$\sum_{i=1}^{a} \tau_i = 0,\ \sum_{j=1}^{b} \beta_j = 0,\ \sum_{k=1}^{c} \gamma_k = 0,\ \sum_{i=1}^{a} (\tau\beta)_{ij} = \sum_{j=1}^{b} (\tau\beta)_{ij} = 0,\ \sum_{i=1}^{a} (\tau\gamma)_{ik} = \sum_{k=1}^{c} (\tau\gamma)_{ik} = 0,$$

$$\sum_{j=1}^{b}(\beta\gamma)_{jk} = \sum_{k=1}^{c}(\beta\gamma)_{jk} = 0,\ \sum_{i=1}^{a}(\tau\beta\gamma)_{ijk} = \sum_{j=1}^{b}(\tau\beta\gamma)_{ijk} = \sum_{k=1}^{c}(\tau\beta\gamma)_{ijk} = 0$$

The design will test the following hypotheses:

$$H_0\colon \tau_i = 0 \text{ vs. } H_1\colon \tau_i \neq 0$$
$$H_0\colon \beta_j = 0 \text{ vs. } H_1\colon \beta_j \neq 0$$
$$H_0\colon \gamma_k = 0 \text{ vs. } H_1\colon \gamma_k \neq 0$$
$$H_0\colon (\tau\beta)_{ij} = 0 \text{ vs. } H_1\colon (\tau\beta)_{ij} \neq 0$$
$$H_0\colon (\tau\gamma)_{ik} = 0 \text{ vs. } H_1\colon (\tau\gamma)_{ik} \neq 0$$
$$H_0\colon (\beta\gamma)_{jk} = 0 \text{ vs. } H_1\colon (\beta\gamma)_{jk} \neq 0$$
$$H_0\colon (\tau\beta\gamma)_{ijk} = 0 \text{ vs. } H_1\colon (\tau\beta\gamma)_{ijk} \neq 0$$

Each H_0 assumes that there is no difference in average WPM across factor levels and each H_1 assumes that there is at least one average WPM that differs across factor levels.

Results

Data:

The data was collected through eight tests, one for each treatment combination. A random number generator was used to ensure that the order of the runs was randomized. The tests were taken five minutes apart to minimize any bias from warming up, typing fatigue, and eye strain.

Table 1 - Incomplete Blocking in 2^3 Factorial Design, Data

Treatment Combination	**A** Font Size	**B** Text Length	**C** Screen Brightness	**WPM**
low a, low b, low c → (1)	Size 2	25 words	50%	131
high a, low b, low c → (a)	Size 5	25 words	50%	118
low a, high b, low c → (b)	Size 2	50 words	50%	126
high a, high b, low c → (ab)	Size 5	50 words	50%	112
low a, low b, high c → (c)	Size 2	25 words	100%	118
high a, low b, high c → (ac)	Size 5	25 words	100%	103
low a, high b, high c → (bc)	Size 2	50 words	100%	112
high a, high b, high c → (abc)	Size 5	50 words	100%	112

Table 2 - Sign Table for Incomplete Blocking in 2^3 Factorial Design

Treatment Combination	Factorial Effect							
	I	**A**	**B**	**AB**	**C**	**BC**	**ABC**	**Block**
(1)	1	-1	-1	1	-1	1	-1	1
a	1	1	-1	-1	-1	-1	1	2
b	1	-1	1	-1	-1	1	1	2
ab	1	1	1	1	-1	-1	-1	1
c	1	-1	-1	1	1	-1	1	2
ac	1	1	-1	-1	1	1	-1	1
bc	1	-1	1	-1	1	-1	-1	1
abc	1	1	1	1	1	1	1	2

Table 3 - Block Assignments for Incomplete Blocking in 2^3 Factorial Design

Block 1	**Block 2**
(1) = 131	a = 118
ab = 112	b = 126
ac = 103	c = 118
bc = 112	abc = 112

Block 1 has all of the treatment combinations with a minus sign for ABC and Block 2 has all of the treatment combinations with a plus sign for ABC.

Contrasts:

The contrasts can be obtained by the general equation:

$$contrast_{AB\ldots K} = (a \pm 1)(b \pm 1)\ldots(k \pm 1)$$ (Equation 6.21 from the textbook, pg. 216)

Factor Effect Estimates:

The effect estimates can be calculated by the following equation:

$$\frac{(contrast)^2}{2^{k-p}}$$, where k=3 and p=1

Table 4 - Factor Effect Estimates

Factor	Effect Estimate
ABC (Block)	2.00
A (Font Size)	-5.25
B (Text Length)	-1.00
C (Screen Brightness)	-5.25
AB (Font Size*Text Length)	1.75
AC (Font Size*Screen Brightness)	1.50
BC (Text Length*Screen Brightness)	1.75

Generally, all factors are included in the ANOVA table, but that is not the case here with an unreplicated Incomplete Blocking in 2^3 Factorial Design. As mentioned in the methods section, without replicates, the error term would result in zero degrees of freedom, running the risk of incorrect analysis. Therefore, some of the higher interaction terms must be pooled into the error term. The factors to be pooled were selected based on the magnitude of their estimated effect. Although the effect estimates in our experiment are very similar, we will select the factor with the lowest value to pool, which is AC (font size and screen brightness interaction term).

Table 5 - ANOVA Table for Typing Test Experiment

Source	SS	df	MS	F-score	p-value
ABC (Block)	32.0	1	32.0	1.778	0.410
A (Font Size)	220.5	1	220.5	12.250	0.177
B (Text Length)	8.0	1	8.0	0.444	0.626
C (Screen Brightness)	220.5	1	220.5	12.250	0.177
AB (Font Size*Text Length)	24.5	1	24.5	1.361	0.451
BC (Text Length*Screen Brightness)	24.5	1	24.5	1.361	0.451
Error	18.0	1	18.0		
Total	548.0	7			

$F_{0(block)} = 1.778 < F_{(0.05,1,1)} = 161.4 \rightarrow$ Block effect (ABC) is insignificant

$F_{0(A)} = 12.250 < F_{(0.05,1,1)} = 161.4 \rightarrow$ Main effect A is insignificant

$F_{0(B)} = 0.444 < F_{(0.05,1,1)} = 161.4 \rightarrow$ Main effect B is insignificant

$F_{0(C)} = 12.250 < F_{(0.05,1,1)} = 161.4 \rightarrow$ Main effect C is insignificant

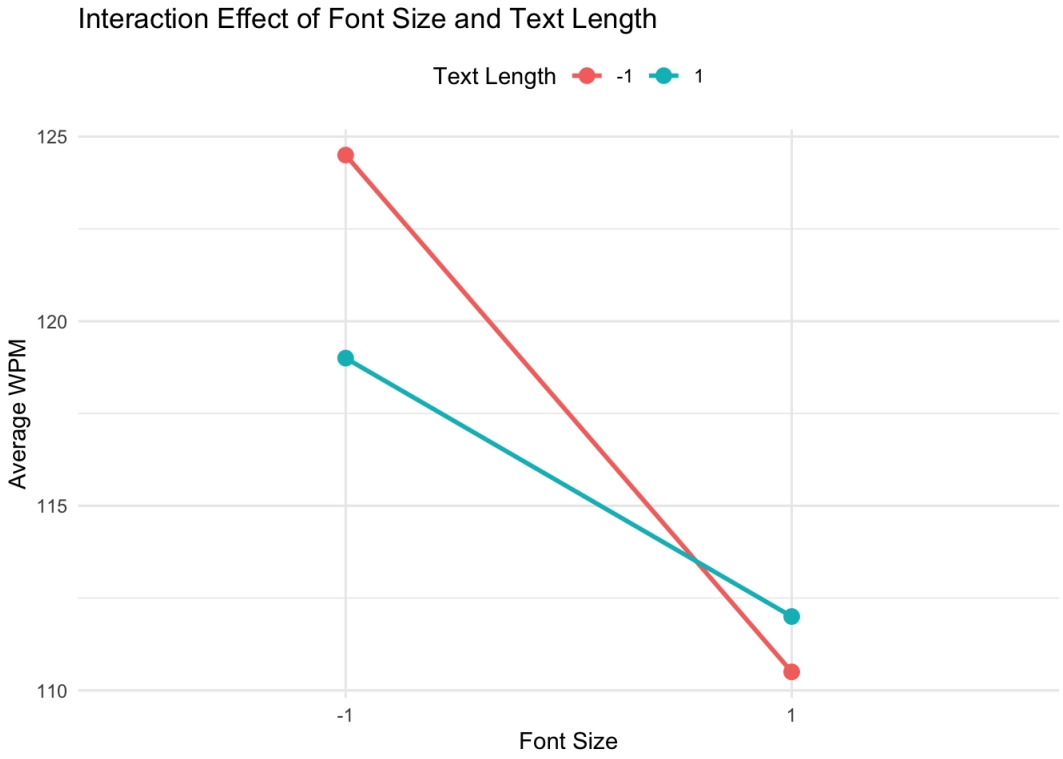
$F_{0(AB)} = 1.361 < F_{(0.05,1,1)} = 161.4 \rightarrow$ Interaction effect AB is insignificant

$F_{0(BC)} = 1.361 < F_{(0.05,1,1)} = 161.4 \rightarrow$ Interaction effect BC is insignificant

Inference:

Since none of the factors have a p-value that is less than the $\alpha = 0.05$ significance level and all of the F_0 values are also less than the critical value $F_{(0.05,1,1)}$, there is not enough evidence to reject H_0. While font size and screen brightness come close, we conclude that none of the factors have a significant effect on typing speed.

Figure 1 - Interaction Effect of Font Size and Text Length



Since the lines on the interaction plot intersect, it tells us that there is likely an interaction between font size and text length. Interestingly, from our ANOVA table, we concluded that this interaction effect was insignificant at the $\alpha = 0.05$ significance level. A closer look shows that the slopes of these two lines appear to be similar, suggesting that this interaction is very small. Assuming this interaction is significant, the plot shows that font size at the low level and text length at the low level are optimal conditions for our user's typing speed.

Conclusion

The results of the experiment provided an insightful analysis of ergonomic and environmental factors on typing speed. We hypothesized why certain changes in our factors can introduce unfamiliarity to the user experience and interfere with their typing speed, but the hypotheses were not supported by the results. Running the experiment with a replicated design can offer

more concrete and consistent results, such as explaining the inconsistencies between the ANOVA table and the interaction plot of font size and text length.

Future studies may include looking at additional factors that impact typing speed, such as keyboard size, screen size, and ambient lighting. This could further help us assess the best computer and environment settings for typing performance and productivity.

From our experiment, we conclude that font size, text length, and screen brightness do not significantly impact typing speed for our user. However, this does not mean that they are insignificant for everyone, as our data does not represent the general population. Ultimately, the ideal conditions would look different for each individual, which is why customizable options on interfaces and devices are essential for optimizing user performance and productivity.

Appendix

Citations:

Miodec. “A Minimalistic, Customizable Typing Test.” *Monkeytype*, monkeytype.com/. Accessed 13 Dec. 2024.

Montgomery, Douglas C. *Design and Analysis of Experiments*. 10th ed., Wiley.

R Code:

ANOVA Model

```
type <- data.frame(
  font = c(-1, 1, -1, 1, -1, 1, -1, 1),
  length = c(-1, -1, 1, 1, -1, -1, 1, 1),
  brightness = c(-1, -1, -1, -1, 1, 1, 1, 1),
  wpm = c(131, 118, 126, 112, 118, 103, 112, 112)
)

type$fontlength <- type$font * type$length
type$fontbrightness <- type$font * type$brightness
type$lengthbrightness <- type$length * type$brightness
type$fontlengthbrightness <- type$font * type$length * type$brightness

model <- aov(wpm ~ font + length + brightness
             + fontlength + lengthbrightness + fontlengthbrightness,
             data = type)
summary(model)
```

Interaction Plot of Font Size and Length of Text

```
summary_fontlength <- type %>%
  group_by(font, length) %>%
  summarise(mean_wpm = mean(wpm), .groups = "drop")
ggplot(summary_fontlength, aes(x = factor(font), y = mean_wpm, color =
factor(length), group = length)) +
  geom_point(size = 3) +
  geom_line(size = 1) +
  labs(x = "Font Size", y = "Average WPM", color = "Length of Text") +
  theme_minimal() +
  ggtitle("Interaction Effect of Font Size and Length of Text") +
  theme(legend.position = "top")
```

Additional Figures:

Sample MonkeyType Tests

Figure 2 - Sample Test of Font Size 2

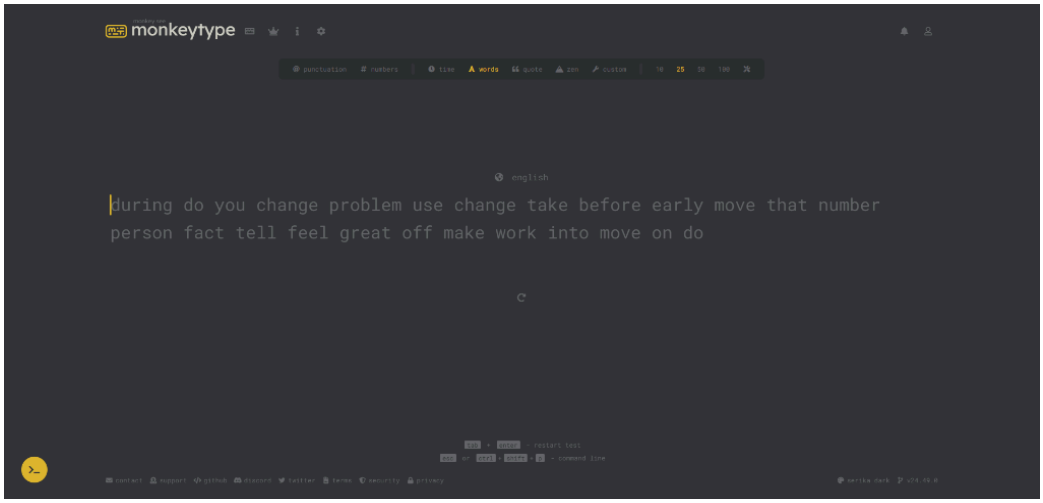
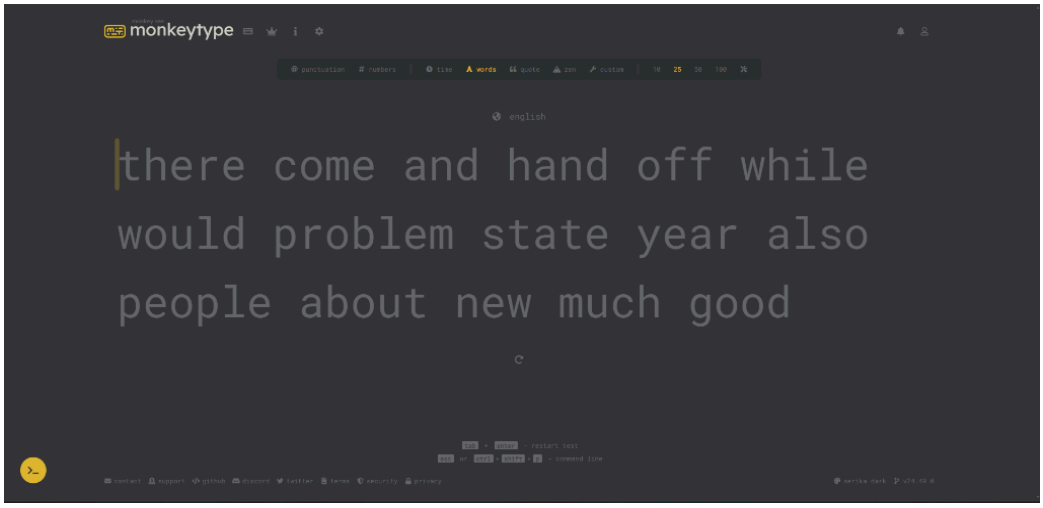


Figure 3 - Sample Test of Font Size 5



Experiment Run Results

Figure 4 - low a, low b, low c → (1); font size: 2, text length: 25, screen brightness: 50%

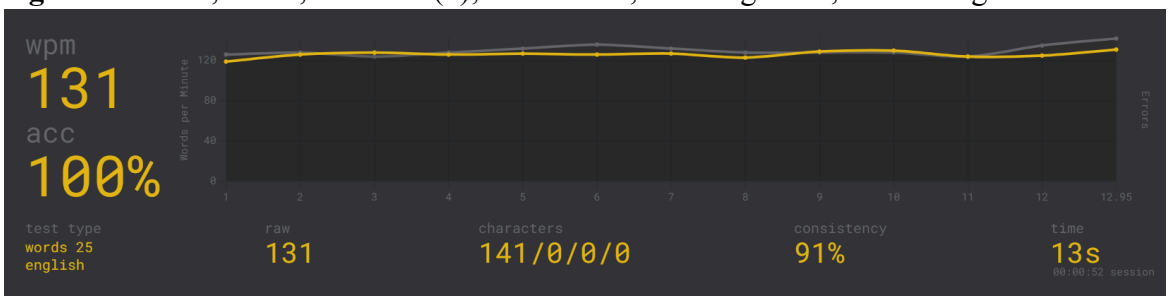


Figure 5 - high a, low b, low c → (a); font size: 5, text length: 25, screen brightness: 50%

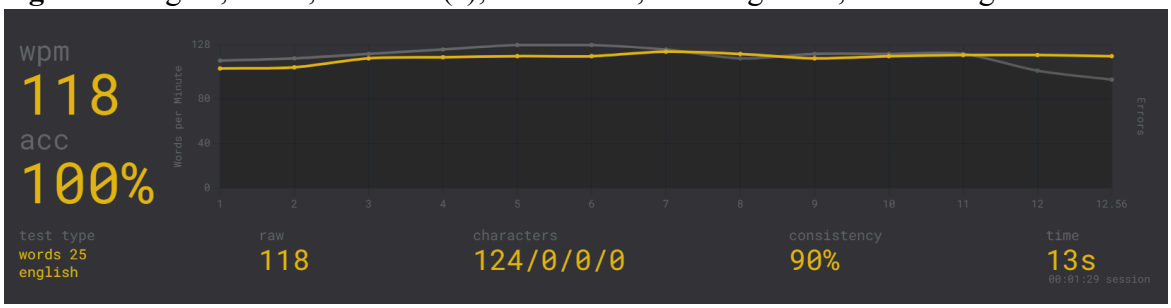


Figure 6 - low a, high b, low c → (b); font size: 2, text length: 50, screen brightness: 50%

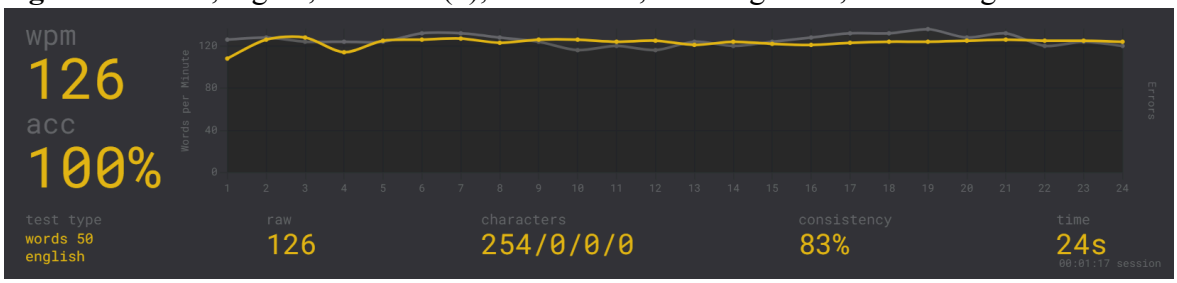


Figure 7 - high a, high b, low c → (ab); font size: 5, text length: 50, screen brightness: 50%

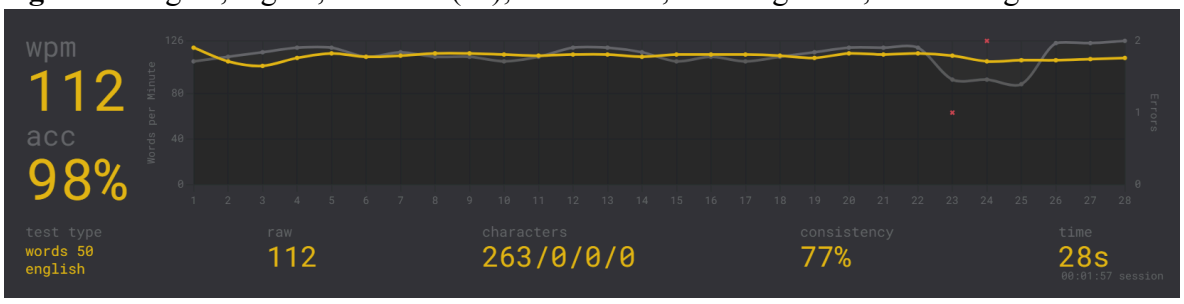


Figure 8 - low a, low b, high c → (c); font size: 2, text length: 25, screen brightness: 100%

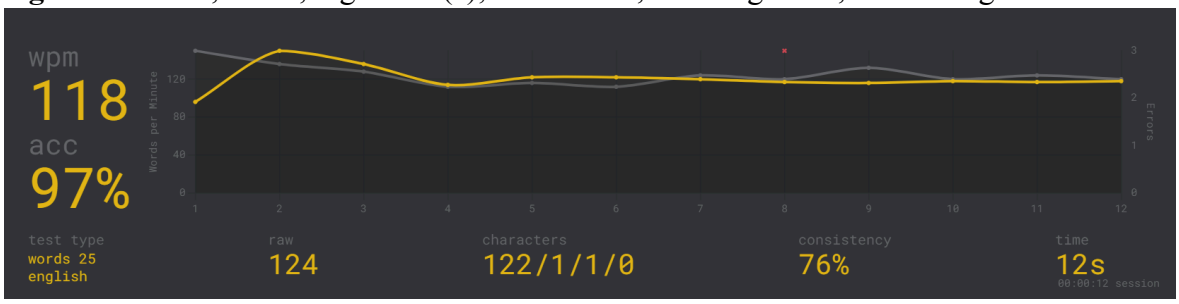


Figure 9 - high a, low b, high c → (ac); font size: 5, text length: 25, screen brightness: 100%

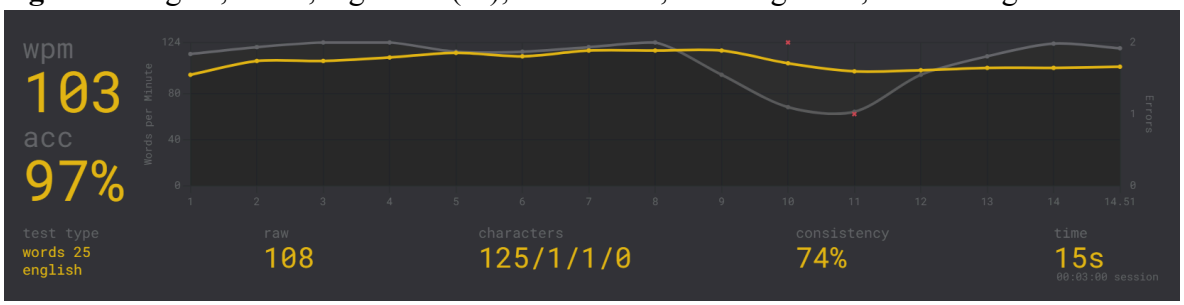


Figure 10 - low a, high b, high c → (bc); font size: 2, text length: 50, screen brightness: 100%

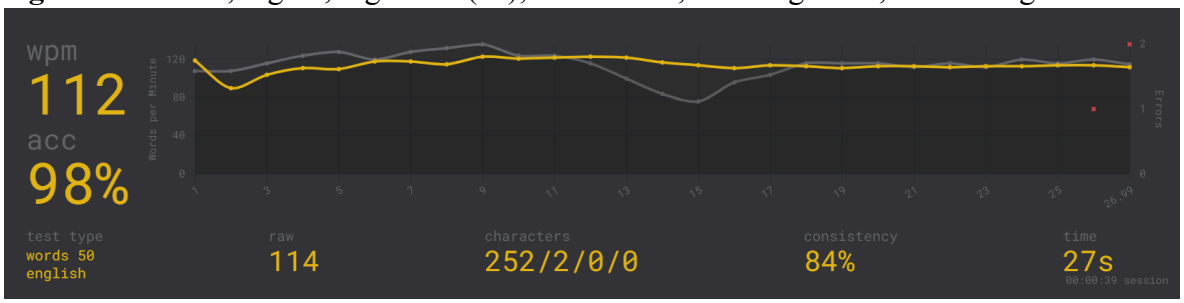


Figure 11 - high a, high b, high c → (abc); font size: 5, text length: 50, screen brightness: 100%