Orthographic Processing in School-age Children - Descriptive Statistics Eye Tracking Data

Brief Introduction

Orthographic awareness (OA) — the ability to recognize permissible letter patterns in a given writing system—is an important component of reading development. In alphabetic languages such as English, OA supports both decoding and word recognition by enabling readers to distinguish between legal and illegal letter sequences. The current study investigates orthographic processing in school-age children (grades 3–6) across three groups: children with dyslexia (n = 28), children with compensated dyslexia (n = 17), and children with typical development (TD, n = 23). By examining how these groups differ in their orthographic decision-making, the study aims to better understand the mechanisms underlying persistent and resolved reading difficulties.

To assess OA, participants completed a visual world eye-tracking task in which they were asked: **"Which word looks most like a real English word?"** Each trial presented four non-word options that varied in orthographic probability and legality:

- A high-probability (high-ortho) item resembling real English words,
- A low-probability (low-ortho) item with less typical letter sequences,
- An illegal item that violates English orthographic rules,
- An unpronounceable item with no plausible phonological form.

Participants completed 18 trials, with option locations and trial order randomized. The task was administered using E-Prime with eye-tracking data collected concurrently.

This report investigates group differences across multiple dimensions of task performance, including:

1. Response time when selecting high-ortho and low-ortho items,
2. Accuracy, based on criteria where high-ortho or both high/low-ortho selections are considered correct,
3. Eye movement metrics, such as fixation count and total dwell time
4. Orthographic interference ratios, including the relative attention (via dwell time) given to legal vs. illegal options.

Inclusion Criteria

Participants were included in the analyses if they met both of the following eye-tracking experiment criteria:

- Accuracy: Correctly identified at least 67% of trials (≥12/18), using the high/low orthographic items as correct choices.
- Visual Engagement: Had at least 12 trials in which they visually inspected all four options (i.e., no fixation count value was zero across the four interest areas).

This inclusion process was implemented to ensure that participants understood the task instructions and attended to all the presented stimuli before making their selection. By applying these filters, the aim was to increase the reliability of the response time and eye-tracking measures used in subsequent analyses.

Based on this inclusion criteria, the TD group had 22 participants, compensated group had 16 participants and the dyslexia group had 28 participants.

Descriptive Statistics

1. Response Time (RT) when High_ortho is selected

Group	Total_Trials
TD	302
Dyslexia	350
Compensated	211

Group	Min	Max	Mean	SD
TD	10	17	13.72727	1.856310
Dyslexia	7	17	12.50000	2.317406
Compensated	8	17	13.18750	2.833578

For the response time analysis involving trials where participants selected the High_Ortho option, a total of 302 trials were included from the TD group, 350 from the dyslexia group, and 211 from the compensated group. On average, participants contributed between 12 and 14 trials each (TD: M = 13.73, SD = 1.86; Dyslexia: M = 12.50, SD = 2.32; Compensated: M = 13.19, SD = 2.83), with the number of High_Ortho selections ranging from 7 to 17 trials.

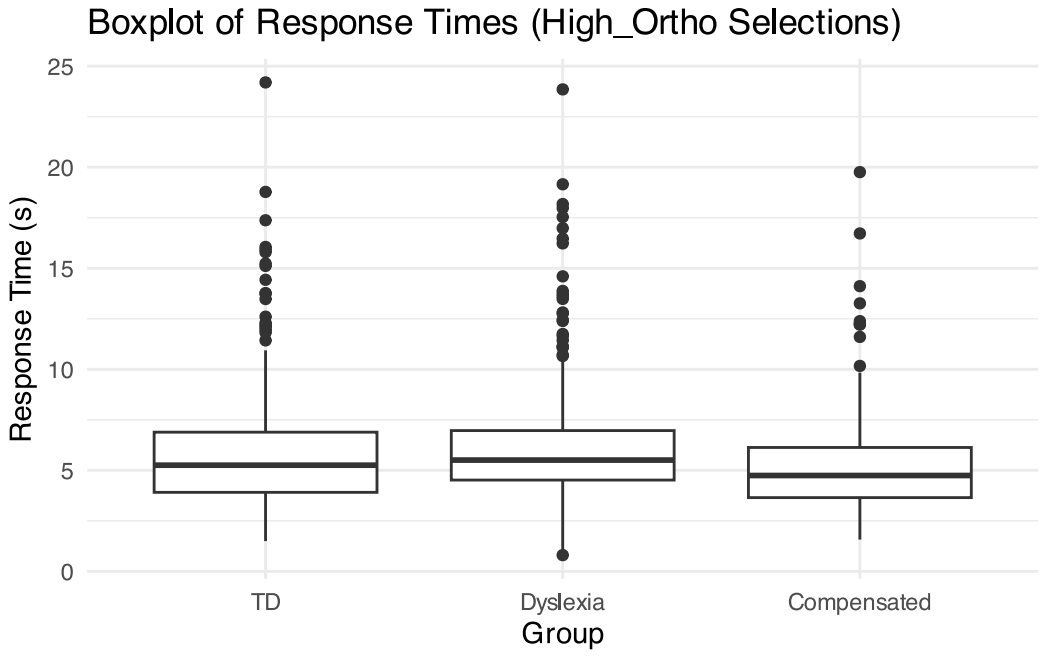
Descriptive statistics for response time (in seconds) on trials where participants selected the high-orthographic probability item are presented in Table 1.

Table 1: Response Time Summary (in seconds) for High_Ortho Selections

By Reading Group

Group	Mean	SD	Min	Q1	Median	Q3	Max
TD	5.86	3.14	1.50	3.91	5.25	6.89	24.20
Dyslexia	6.15	2.95	0.80	4.52	5.51	6.97	23.85
Compensated	5.23	2.59	1.57	3.65	4.74	6.13	19.76

The TD group had a mean response time of 5.86 seconds (SD = 3.14), the dyslexia group averaged 6.15 seconds (SD = 2.95), and the compensated dyslexia group averaged 5.23 seconds (SD = 2.59). Median response times were 5.25, 5.51, and 4.74 seconds for the TD, dyslexia, and compensated groups, respectively. The interquartile ranges were similar across groups: 3.91–6.89 seconds for TD, 4.52–6.97 seconds for dyslexia, and 3.65–6.13 seconds for the compensated group. Although all groups included some long response times (e.g., maximums exceeding 19 seconds), overall performance patterns suggest comparable timing across groups when selecting high-orthographic items.




```
# A tibble: 18 × 4
   participant_id Group       OrthoET_trial_number RT_sec
   <chr>          <fct>                      <dbl>  <dbl>
 1 c171071        TD                            13   24.2
 2 c194002        Dyslexia                      18   23.9
 3 c194019        Compensated                    9   19.8
```

```
 4 c194049        Dyslexia                      1   19.2
 5 c171014        TD                            1   18.8
 6 c194036        Dyslexia                      2   18.2
 7 c194049        Dyslexia                      8   18.0
 8 c194002        Dyslexia                      5   17.5
 9 c171144        TD                            4   17.4
10 c194007        Dyslexia                      4   17.0
11 c194031        Compensated                   1   16.7
12 c194001        Dyslexia                      1   16.5
13 c194007        Dyslexia                     13   16.2
14 c171071        TD                            5   16.1
15 c171071        TD                           15   15.9
16 c171144        TD                            6   15.8
17 c171144        TD                           10   15.2
18 c191035        TD                            8   15.1
```

Visual inspection of the boxplot revealed several response times above 15 seconds in each group, suggesting the presence of potential outliers. These long RTs were retained in the analysis as they may reflect natural variation in decision-making time rather than noise. However, they may warrant further examination in subsequent analyses.

2. Response Time (RT) when Low_ortho is selected

For Low_Ortho selections, fewer trials contributed to the response time analysis, with 91 trials from the TD group, 145 from the dyslexia group, and 77 from the compensated group. Participants selected the Low_Ortho option on average 4 to 5 times (TD: M = 4.14, SD = 1.83; Dyslexia: M = 5.18, SD = 1.83; Compensated: M = 4.81, SD = 2.83), with a minimum of 1 and a maximum of 10 selections per participant.

Group	Total_Trials
TD	91
Dyslexia	145
Compensated	77

Group	Min	Max	Mean	SD
TD	1	8	4.136364	1.833432
Dyslexia	1	8	5.178571	1.826828
Compensated	1	10	4.812500	2.833578

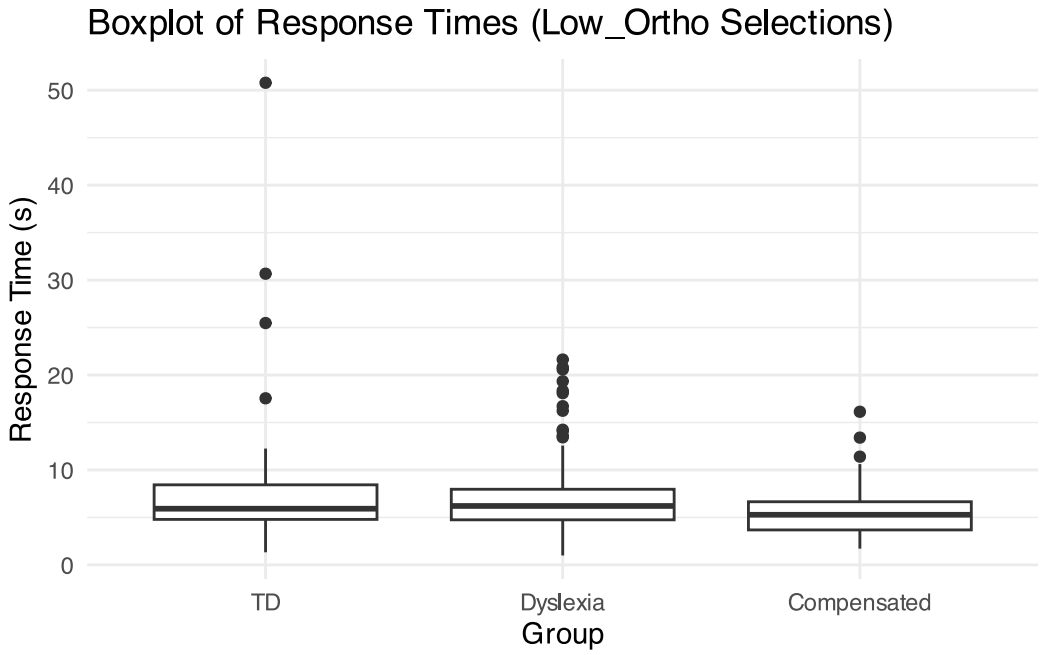
Descriptive statistics for response time (in seconds) on trials where participants selected the low-orthographic probability item are presented in Table 2.

Table 2: Response Time Summary (in seconds) for Low_Ortho Selections

By Reading Group

Group	Mean	SD	Min	Q1	Median	Q3	Max
TD	7.32	6.29	1.33	4.79	5.92	8.43	50.78
Dyslexia	7.19	3.87	0.99	4.75	6.21	7.97	21.63
Compensated	5.70	2.65	1.71	3.69	5.28	6.65	16.13

The typical development (TD) group had a mean response time of 7.32 seconds (SD = 6.29), while the dyslexia and compensated dyslexia groups had means of 7.19 seconds (SD = 3.87) and 5.70 seconds (SD = 2.65), respectively. The TD group also exhibited the widest range of response times, with a maximum of 50.78 seconds.




```
# A tibble: 3 × 3
  participant_id OrthoET_trial_number RT_sec
  <chr>                         <dbl>  <dbl>
1 c143278                           1   50.8
2 c191025                           2   30.7
3 c171071                           1   25.5
```

Visual inspection of boxplots indicated the presence of a few unusually long trials across all groups, particularly in the TD group, suggesting potential outliers. These values were retained in the analysis, but they may warrant further consideration in follow-up analyses.

3. Accuracy scores by group when High_ortho was selected

Descriptive statistics for accuracy based on the selection of high-ortho probability items are presented in Table 3.

Table 3: Accuracy for High_Ortho Selections Only

Proportion of Trials Where High_Ortho Was Selected (Out of 18)

Group	Mean_Accuracy	SD
TD	0.76	0.43
Dyslexia	0.69	0.46
Compensated	0.73	0.44

Accuracy was calculated as the proportion of trials (out of 18) on which each participant selected the High_Ortho option. The typical development (TD) group demonstrated the highest mean accuracy (M = 0.76, SD = 0.43), followed by the compensated group (M = 0.73, SD = 0.44) and the dyslexia group (M = 0.69, SD = 0.46).

4. Accuracy Scores by Group when High and Low Ortho were selected

Descriptive statistics for accuracy using a broader criterion—counting both high- and low-orthographic probability selections as correct—are presented in Table 4.

Table 4: Accuracy for High or Low_Ortho Selections

Proportion of Trials Where Either High or Low_Ortho Was Selected (Out of 18)

Group	Mean_Accuracy	SD
TD	0.99	0.09
Dyslexia	0.98	0.13
Compensated	1.00	0.00

All groups performed near ceiling under this scoring approach. The typical development (TD) group achieved a mean accuracy of 0.99 (SD = 0.09), the dyslexia group had a mean of 0.98 (SD = 0.13), and the compensated group performed at 1.00 (SD = 0.00). This pattern suggests that across reading profiles, children were highly likely to select one of the two orthographically legal options on each trial.

5. Proportion of fixations on each IA type

Table 5 presents the mean proportion of fixations on each response option, calculated as the percentage of total fixations per trial.

Table 5: Proportion of Fixations by Option Type

Mean (SD) % of Fixations per Group

Group	High Ortho	Low Ortho	Illegal	Unpronounce-able
TD	35.27 (13.02)	27.58 (12.54)	19.23 (10.39)	17.93 (8.66)
Dyslexia	33.14 (13.38)	28.77 (12.5)	19.66 (9.9)	18.42 (9.09)
Compensated	33.92 (12.16)	28.33 (12.12)	18.95 (8.8)	18.81 (9.15)

Across all groups, participants fixated most frequently on the high-orthographic option (TD: 35.27%, Dyslexia: 33.14%, Compensated: 33.92%), followed by the low-orthographic option. Illegal and unpronounceable items received fewer fixations overall, with proportions typically under 20%. Standard deviations were relatively consistent across groups

6. Total Dwell Time on each option

Table 6 presents the average dwell time (in seconds) for each response option type.

Table 6: Dwell Time on Each Option Type

Mean (SD) Dwell Time in Seconds per Group

Group	High Ortho	Low Ortho	Illegal	Unpronounceable
TD	2.47 (1.65)	1.63 (1.61)	0.64 (0.65)	0.54 (0.51)
Dyslexia	2.41 (1.32)	1.98 (1.72)	0.78 (0.86)	0.76 (0.86)
Compensated	2.02 (1.12)	1.6 (1.32)	0.62 (0.53)	0.59 (0.5)

All groups spent the most time viewing the high-orthographic item, but the dyslexia group showed notably longer dwell times for low-orthographic, illegal, and unpronounceable items compared to the other groups. For example, mean dwell time on low-orthographic items was 1.98 seconds for the dyslexia group, versus 1.63 and 1.60 seconds for the TD and compensated groups, respectively. A similar trend was observed for illegal and unpronounceable options.

7. Ratio of Total Dwell Time on Legal vs. Illegal Options

```r
## Classify IA as legal and illegal
dwell_ratio_data <- ortho_data %>%
  filter(!is.na(OrthoET_IA_dwell_time)) %>%
  mutate(
    dwell_time_sec = OrthoET_IA_dwell_time / 1000,
    Legal_Status = case_when(
      OrthoET_IA_label %in% c("High_Ortho_IA", "Low_Ortho_IA") ~ "Legal",
      OrthoET_IA_label %in% c("Illegal_IA", "Unpron_IA") ~ "Illegal",
      TRUE ~ NA_character_
    )
  )

## Computing Ratio

# Sum dwell time by participant × trial × Legal status
dwell_ratio_trial <- dwell_ratio_data %>%
  group_by(participant_id, OrthoET_trial_number, Group, Legal_Status) %>%
  summarise(
    total_dwell = sum(dwell_time_sec, na.rm = TRUE),
    .groups = "drop"
  ) %>%
  pivot_wider(
    names_from = Legal_Status,
    values_from = total_dwell
  ) %>%
  mutate(
    dwell_ratio_legal_vs_illegal = Legal / Illegal
  )

## Summarize ratio by group

dwell_ratio_summary <- dwell_ratio_trial %>%
  mutate(Group = factor(Group, levels = c("TD", "Dyslexia", "Compensated"))) %>%
  group_by(Group) %>%
  summarise(
    Mean_Ratio = mean(dwell_ratio_legal_vs_illegal, na.rm = TRUE),
    SD = sd(dwell_ratio_legal_vs_illegal, na.rm = TRUE),
    .groups = "drop"
  )

## table

dwell_ratio_summary %>%
  gt() %>%
  tab_header(
    title = "Ratio of Dwell Time on Legal vs. Illegal Options",
    subtitle = "Mean (SD) Dwell Time Ratio by Group"
```

```
) %>%
fmt_number(columns = everything(), decimals = 2)
```

Ratio of Dwell Time on Legal vs. Illegal Options

Mean (SD) Dwell Time Ratio by Group

Group	Mean_Ratio	SD
TD	Inf	NaN
Dyslexia	Inf	NaN
Compensated	Inf	NaN