

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

## Inclusion Criteria for eye tracking data

All participants were included for investigating accuracy of responses across groups.

However, the following inclusion criteria was followed for the eye tracking analyses (i.e., for response time, fixations and dwell times):

- Accuracy: Correctly identified at least 67% of trials ( $\geq 12/18$ ), 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.

## Descriptive Statistics

### 1. Overall Response Choices Chosen across Groups

Before analyzing accuracy based on scoring criteria, the raw distribution of response choices across groups was examined (see Table 1). All participants met the task accuracy inclusion criterion, so no participants were excluded from the analyses. The final sample included 23 children with typical development (TD), 28 with dyslexia, and 17 with compensated dyslexia.

Table 1: Distribution of Response Choices by Group  
Mean (SD) Number of Trials per Response Type (out of 18)

Group	High	Low	Illegal	Unpron
TD	13.61 (1.9)	4.26 (1.89)	0.13 (0.34)	0 (0)
Dyslexia	12.5 (2.32)	5.18 (1.83)	0.25 (0.8)	0.07 (0.26)
Compensated	13 (2.85)	5 (2.85)	0 (0)	0 (0)

On average, participants in all three groups most frequently selected the high-orthographic probability option, with TD children choosing this option on 13.61 of 18 trials ( $SD = 1.90$ ), children with dyslexia on 12.50 trials ( $SD = 2.32$ ), and the compensated group on 13.00 trials ( $SD = 2.85$ ). The low-orthographic option was selected less frequently, while illegal and unpronounceable options were rarely chosen.

## 2. 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 2.

Table 2: 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	0.72	0.45

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 ( $M = 0.72$ ,  $SD = 0.45$ ) and the dyslexia group ( $M = 0.69$ ,  $SD = 0.46$ ).

## 3. 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 3.

Table 3: 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	0.08
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 ( $SD = 0.08$ ), the dyslexia group had a mean of 0.98 ( $SD = 0.13$ ), and the compensated group performed at 1.00 ( $SD = 0.00$ ).

## 4. Response Time (RT) when High\_ortho is selected

For the response time analysis involving trials where participants selected the High\_Ortho option, a total of 66 (TD:  $n = 22$ , Dyslexia:  $n = 28$ , Compensated:  $n = 16$ ) participant's eye tracking data

was included. A total of 302 trials were included from the TD group, 350 from the dyslexia group, and 211 from the compensated group.

Summary (min/max/mean) number of High-ortho selections by group				
Group	Min	Max	Mean	SD
TD	10.00	17.00	13.73	1.86
Dyslexia	7.00	17.00	12.50	2.32
Compensated	8.00	17.00	13.19	2.83

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 4.

Table 4: 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 visual inspection of the raw response time data revealed a small number of unusually long trials (e.g., exceeding 20 seconds), which could reflect momentary task disengagement or other non-task-related factors. To reduce the influence of extreme values while still retaining all trials, response times were Winsorized at the 5th and 95th percentiles within each group. Descriptive statistics for the Winsorized response times are presented in Table 5.

Table 5: Winsorized Response Time Summary (in seconds) for High\_Ortho Selections  
By Reading Group (5th and 95th Percentiles Winsorized)

Group	Mean	SD	Min	Q1	Median	Q3	Max
TD	5.71	2.58	2.03	3.91	5.25	6.89	12.07
Dyslexia	6.00	2.23	2.86	4.52	5.51	6.97	11.70
Compensated	5.07	2.01	2.29	3.65	4.74	6.13	9.81

After Winsorizing, the mean response time for the TD group was 5.71 seconds (SD = 2.58), for the dyslexia group 6.00 seconds (SD = 2.23), and for the compensated group 5.07 seconds (SD = 2.01). Group medians followed a similar pattern, with the dyslexia group again slightly slower (5.51 seconds) than TD (5.25 seconds) and compensated (4.74 seconds) participants. The Winsorized values suggest that all three groups were comparable in overall response speed when selecting high-orthographic items, though children with dyslexia remained marginally slower on average.

## 5. 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	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 6.

Table 6: 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.

As with the High\_Ortho trials, response times for Low\_Ortho selections were Winsorized at the 5th and 95th percentiles within each group to reduce the influence of extreme outliers while retaining all trials. Table 7 presents descriptive statistics for the Winsorized response times.

Table 7: Winsorized Response Time Summary (in seconds) for Low\_Ortho Selections

By Reading Group (5th and 95th Percentiles Winsorized)							
Group	Mean	SD	Min	Q1	Median	Q3	Max
TD	6.51	2.80	2.26	4.79	5.92	8.43	12.21
Dyslexia	7.07	3.27	3.02	4.75	6.21	7.97	15.84
Compensated	5.58	2.24	2.50	3.69	5.28	6.65	10.21

The dyslexia group showed the longest mean response time at 7.07 seconds (SD = 3.27), followed by the TD group at 6.51 seconds (SD = 2.80), and the compensated group at 5.58 seconds (SD = 2.24). Median response times reflected the same pattern. While all three groups spent slightly more time on Low\_Ortho selections than on High\_Ortho ones, the differences between groups were more pronounced in this condition, with the dyslexia group consistently slower on average.

## 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	Unpronounceable
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. Ille-

gal 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

```
## 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 x trial x 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