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

Brief Introduction

Orthographic awareness (OA) — the ability to recognize and evaluate letter patterns based on the rules and regularities of a 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 more and less probable 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 (≥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).

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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.

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6. Raw Fixations on each IA type

Eye-tracking data from 66 participants (TD: n = 22, Dyslexia: n = 28, Compensated: n = 16) were included in the fixation analyses. Table 8 presents the mean number of fixations on each response option type, collapsed across all trials and participants within each group. Across groups, participants made the greatest number of fixations on the high-orthographic item (TD: M = 3.67, SD = 2.31; Dyslexia: M = 3.38, SD = 1.79; Compensated: M = 3.34, SD = 1.77), followed by the low-orthographic item. Illegal and unpronounceable options consistently received fewer fixations, with means below 2 for all groups.

Table 8: Number of Fixations on Each Option Type

Mean (SD) Fixation Count by Group and Item Type

Group	High Ortho	Illegal Ortho	Low Ortho	Unpronounceable Ortho
TD	3.67 (2.31)	2 (1.45)	2.94 (2.32)	1.82 (1.12)
Dyslexia	3.38 (1.79)	1.98 (1.21)	3.03 (1.83)	1.89 (1.25)
Compensated	3.34 (1.77)	1.84 (1.14)	2.85 (1.81)	1.8 (1.04)

7. Proportion of fixations on each IA type

Table 9 presents the mean proportion of fixations on each response option, calculated as the percentage of total fixations per trial. A total of 366 trials were included from the TD group, 474 from the dyslexia group, and 273 from the compensated group. Participants contributed between 12 and 18 trials each, with average trial counts per participant as follows: TD (M = 16.64, SD = 1.65), Dyslexia (M = 16.93, SD = 1.74), and Compensated (M = 17.06, SD = 1.88).

Table 9: 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. Illegal and unpronounceable items received fewer fixations overall, with proportions typically under 20%. Standard deviations were relatively consistent across groups

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8. Total Dwell Time on each option

Eye-tracking data from 66 participants (TD: n = 22, Dyslexia: n = 28, Compensated: n = 16) were included in the fixation analyses. Table 10 presents the average dwell time (in seconds) for each response option type.

Table 10: 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.

9. Proportion of Dwell Time on each IA type

Table 11 presents the mean proportion of total dwell time that participants allocated to each option type across all trials.A total of 366 trials were included from the TD group, 474 from the dyslexia group, and 273 from the compensated group. Participants contributed between 12 and 18 trials each, with the following average trial counts per participant: TD (M = 16.64, SD = 1.65), Dyslexia (M = 16.93, SD = 1.74), and Compensated (M = 17.06, SD = 1.88). Participants across all groups spent the greatest proportion of time viewing the high-orthographic item (TD: 47.94%, Dyslexia: 43.18%, Compensated: 43.45%), followed by the low-orthographic item. Illegal and unpronounceable options received comparatively less visual attention, with dwell proportions generally below 15%. The dyslexia and compensated groups spent slightly less time on high-orthographic items and slightly more on low-orthographic and unpronounceable items compared to the TD group, though the overall attentional pattern favoring legal over illegal options was consistent across groups.

Table 11: Proportion of Dwell Time on Each Option Type

Mean (SD) % of Total Dwell Time per Trial by Group

Group	High	Illegal	Low	Unpron
TD	47.94 (18.28)	12.6 (9.36)	28.74 (17.84)	10.71 (7.56)
Dyslexia	43.18 (18.78)	13.08 (9.41)	31.53 (18.06)	12.21 (7.73)
Compensated	43.45 (17.76)	12.72 (7.21)	31.55 (17.83)	12.28 (7.41)

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

Table 12 presents the mean ratio of dwell time on legal versus illegal items, calculated at the trial level.

Table 12: Ratio of Dwell Time on Legal vs. Illegal Options

By Reading Group (excluding trials with 0 illegal dwell time)

Group	Mean	SD	Min	Q1	Median	Q3	Max
Compensated	3.72	2.21	0.63	2.29	3.13	4.66	13.38
Dyslexia	4.02	3.07	0.03	2.10	3.32	5.03	32.34
TD	4.56	3.71	0.00	2.45	3.63	6.13	51.37

Across all groups, participants spent more time fixating on legal (high- and low-orthographic) items than on illegal or unpronounceable ones. The TD group showed the highest average ratio (M = 4.56, SD = 3.71), followed by the dyslexia group (M = 4.02, SD = 3.07) and the compensated group (M = 3.72, SD = 2.21). Although some participants in the TD and dyslexia groups showed extremely high ratios (e.g., up to 51.37 and 32.34, respectively), median values across groups remained in the 3–4 range, suggesting a consistent pattern of preferential visual attention to legal orthographic forms across groups.