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Statistical Analysis for the QS Reading Test

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Executive Summary

Background

Pico Educational Systems Ltd have developed a new online Reading Test that is provided as an optional extra for anyone undertaking their QuickScreen (QS) Dyslexia Test. The test typically takes 30 minutes to complete and is suitable for individuals where English is a first/fluent language. The Reading Test provides users with an indication of their reading level based on several metrics including accuracy, fluency, speed and comprehension. It also provides readers with an indication of whether they might suffer from any possible processing difficulties, or a specific learning difficulty/dyslexia, that may be hampering their reading fluency.

Data has been collated for all candidates who undertook both the QS Dyslexia Test and Reading Test between 1st February 2024 and 21st July 2024. The participants included those who took the test via their university, college or workplace assessment process, along with members of the public (aged 16 to 74) who accessed Pico's services within this period. Participants with a previous positive assessment for dyslexia were considered in the dyslexic group for analysis. The non-dyslexic group included those without a previous assessment and who reported no life-long difficulties with literacy and who did not have a family history of dyslexia. Candidates without a previous assessment but who reported life-long difficulties with literacy or who had a family history of dyslexia were considered "at risk". Note: All participants' data was anonymised by Pico Educational Systems Ltd prior to being provided to Select for analysis and was handled in accordance with their current privacy policy.

This study had two main objectives:

1. Compare the reading measures between the QS Dyslexia and Reading tests to confirm consistency between the results.
2. Explore the Reading Test results split by the dyslexia subgroups. The working hypothesis is that adults with dyslexia are slower readers and slower at processing information and we would expect this to be reflected in the results of the Reading Test.

Headline Results

The headline results from the study are detailed below.

<u>Consistency between the QS Dyslexia and Reading Tests</u>

- The analysis of the data between the QS Dyslexia and Reading Tests highlights that overall, there is good consistency between the reading results of the two tests.
- There is a positive correlation between reading speed (wpm) in the QS Dyslexia Test and Reading Test (correlation coefficient 0.66). There is variation between the reading speeds (which is why the correlation coefficient is not closer to 1) and, on average, the QS Dyslexia Tests reading speed is higher than the Reading Test by 6 wpm.
- The QS Dyslexia Test provides an overall result for each participant that indicates the potential for dyslexia based on the categories: None, Borderline, Mild, Moderate and Strong. There is evidence of an association between the Reading Test reading scores (reading speed, fluency and overall score) and the QS Dyslexia Test overall result with the average score reducing the greater the strength of dyslexia.

- There is evidence that both the QS Dyslexia Test dyslexia quotient and percentile is higher on average for those participants who are flagged in the Reading Test compared to those who are not. The mean dyslexic quotient for those who have been flagged in the reading test as being possibly dyslexic is 4.00 compared to 2.50 for those that have not been flagged, whilst the mean dyslexic percentile is 0.62 compared to 0.37.
- Similarly, we see an association between the QS Dyslexia Test speed of processing (no difficulties, average and difficulties) and the Reading Test dyslexia flag with a greater proportion of participants being flagged in the Reading Test if they have been classified as having difficulties compared to no difficulties (67.5% vs. 7.3%).
- It is important to note that there is not always a one-to-one mapping between the results in the two tests. For example, there are 32.5% participants who have been flagged in the QS Dyslexia Test as having "difficulties" in Speed of Processing but have not been flagged in the Reading Test as being potentially dyslexic/having reading difficulties. However, we know that not all dyslexics have reading difficulties and therefore we would not expect all participants to have been flagged as having difficulties in speed of processing in the QS Dyslexia Test to also have difficulties in reading.
- The optimal QS Dyslexia Test dyslexia quotient cut-off to classify a participant as being flagged in the Reading Test is 49.5%. The dyslexia quotient has moderate predictive capacity of predicting whether a participant will be flagged in the reading test; applying the cut-off to the sample, we find an accuracy of 66.1%.

<u>Reading Test Results by Dyslexia Subgroups</u>

- We found an association between the Reading Test flag and the dyslexic subgroups; 25.5% of non-dyslexics were flagged in the Reading Test, 34.1% of the at-risk group and 51.4% of the dyslexics.
- Note that the non-dyslexic sample has not been formally assessed for dyslexia (some of whom therefore could feasibly be undiagnosed dyslexic and placed in the wrong dyslexia subgroup) and that it is also possible for someone to not have dyslexia, but to have reading difficulties (i.e., it would be accurate that some non-dyslexics are flagged in the Reading Test as having reading difficulties). Consequently, it is not unexpected that some non-dyslexic participants are flagged in the Reading Test (in this case 25.5%).
- It is also perhaps not surprising that approximately 50% of dyslexics are not flagged in the Reading Test. Firstly, we know that not all dyslexics have reading difficulties. Secondly, the dyslexic group in the sample is made up primarily of those who are currently in higher education or graduates in professional jobs. These participants are likely to have attained satisfactory or good levels of literacy and/or reading to reach higher education therefore we would not expect all these samples to have low or below average reading results in the Reading Test. Based on this sample, it seems that around 50% of dyslexic users of the QS Dyslexia and Reading test are fluent readers.
- There is an association between the individual reading metrics in the Reading Test (speed, fluency, accuracy and comprehension) and the dyslexia subgroups where the mean value for each metric is largest for the non-dyslexic group, followed by the at-risk group and then the smallest for the dyslexic group. The only metric where this did not hold is for speed of processing, but it is acknowledged that this is a less accurate measure of speed of processing

than the QS Dyslexia Test as participants are known to rush the Reading Test (and from previous research we have found that difficulties in speed of processing using the QS Dyslexia Test is associated with dyslexia).

- Overall, we find that the data from the Reading Test does support the hypothesis that those with dyslexia have on average, poorer reading speed, accuracy and comprehension.
- The optimal reading fluency cut-off to classify as participant as being dyslexic is 70.7%. The reading fluency has good predictive capacity of predicting whether a participant will be flagged in the reading test and could be considered as a useful initial screener of dyslexia; applying the cut-off to the sample, we find an accuracy of 80%.
- Comparing the results of the Reading Test between those participants where English is their first language and those where it is their second language, we find that a higher proportion of the dyslexic subgroup for participants where English is their second language are flagged in the Reading Test (87%). Typically, we find that reading accuracy, speed and fluency are lower on average for those participants where English is their second compared to first language, but we do not find a difference in vocabulary and general knowledge comprehension. Interestingly, participants with English as a second language take longer on average to complete the Reading test; they are potentially less likely to rush the test than those participants with English as a first language.

Contents

Introduction

Pico Educational Systems Ltd have developed a new online Reading Test that is provided as an optional extra for anyone undertaking their QuickScreen (QS) Dyslexia Test. The test typically takes 30 minutes to complete and is suitable for individuals where English is a first/fluent language. This ensures that the test does not exclude those who have English as a second language (note it is recorded for each participant whether English is a first language). The Reading Test enables a participant to find out:

- How well they read against a number of criteria, along with an overall reading score.
- Areas that need to be developed further.
- If they have any possible processing difficulties, or a specific learning difficulty/dyslexia, that may be hampering their reading fluency.

The online Reading Test is not a full dyslexia screener since there are some people with dyslexia who are fluent readers. However, it is known that often people with dyslexia are significantly slower readers. The Reading Test provides results relating to seven areas:

1. Reading accuracy
2. Reading fluency
3. Silent Reading Speed
4. Comprehension (factual, inference, overview)
5. Comprehension (vocabulary, general knowledge)
6. Comprehension (sequencing, organisation)
7. Overall Reading score

Since its launch the Reading Test has been available free to anyone taking the QS Dyslexia Test and data are being collated on the results of participants for both online tests (dyslexia and reading). The objectives of this study are:

1. A comparison of the results between the QS Dyslexia Test and the Reading Test to confirm consistency between the results. In particular:
    a. A comparison of the reading scores between the two tests.
    b. The level of association between the QS dyslexia quotient and the Reading Test dyslexic flag.
    c. The cut-off point between dyslexia severity and the likelihood of the Reading Test dyslexia flag.
    d. Comparison of the QS speed of processing and Reading Test dyslexia flag.
2. An exploration of the Reading Test results split by whether the participants have been previously diagnosed as being dyslexic, are at-risk of dyslexia or are non-dyslexic. The working hypothesis is that adults with dyslexia are slower readers and slower at processing information. We will explore whether the results of the Reading Test confirm this hypothesis by producing summaries of the Reading Test outputs by dyslexic group. We will also look at how results vary for those participants for whom English is not their first language and identify the optimal cut-off point between reading fluency and the likelihood of being dyslexic.

Data

The data for this study were compiled by Pico Educational Systems Ltd and provided to us for analysis. These included observational data collected from participants who completed both the online QS Dyslexia Test and Reading tests from 1st February 2024 until 21st July 2024, including all candidates who came forward to do the test via their university, college or workplace assessment process and members of the public (aged 17 to 74) who accessed Pico's services within this period.

The data received included results for participants on whether they did or did not have a previous dyslexia diagnosis. This information was used to subset the candidates into the following groups:

- A general non-dyslexic group, which comprised participants who had not been previously assessed for dyslexia and reported that they had not had life-long difficulties with literacy or that they did not have dyslexia in their immediate family (n=184).
- A dyslexic group, which comprised participants who stated that they had previously assessed as dyslexic (n=185).
- An "at risk" group, which comprised participants who had not been previously assessed for dyslexia but reported that they had experience life-long difficulties with literacy or had dyslexia in their immediate family (n=719).

We note that in the dyslexic group, 57% flagged that they had a family history of dyslexia and 52% in the at-risk group (by definition none of the non-dyslexic group had a family history of dyslexia). This is a lower proportion of family history in the dyslexia group compared to other studies that have been undertaken which have previously identified that 80% of cases can be identified by family history (Schumacher et al (2007)).

The data were provided in six Excel spreadsheets, for six separate months of data. These Excel files all had a consistent layout and were combined prior to analysis to create a single dataset. The final data set included the results for each of the tests (QS Dyslexia Test and Reading Test), the subgroup which a participant belonged to (dyslexic, at risk or non-dyslexic) and whether English was a participants first language.

All participants' data was anonymised by Pico Educational Systems Ltd prior to being provided to Select for analysis and was handled in accordance with their current privacy policy.

There are the following limitations associated with the data set that are likely to impact the results:

1. The non-dyslexic group have not been formally assessed for dyslexia. Whilst it is likely that most are non-dyslexic, it is possible that some participants may have unidentified learning problems which means that they may have indicators of dyslexia or processing difficulties but be unaware of these issues. Furthermore, it is recognised that though participants in the non-dyslexic group may not have previously received a formal dyslexia diagnosis, it is possible that this group may in fact contain a small number of previously undiagnosed dyslexics. Therefore, where the Reading Test reports possible processing difficulties for a participant in the non-dyslexic group, it is understood that this subject could in fact have undiagnosed dyslexia.
2. Due to the organisations that utilise the QS Dyslexia and Reading tests, the dyslexic group will certainly contain participants who are undergraduates or graduates, and those who may

now be in professional careers (since most participants are from university, college or workplace assessments). These participants will likely have made improvements in their learning since their previous diagnosis was received, which may have not been very recently, as they will have attained satisfactory or good levels of literacy by the time they entered higher education. Research shows that with the right strategies people with dyslexia can achieve high levels of literacy (Brèthes et al (2022), Fink (1998)). Any well-compensated individuals may be asymptomatic or more borderline in their dyslexia symptoms and reading abilities and therefore the Reading Test may find it more difficult to identify these lesser symptoms.

3. When interpreting the results of this analysis, the validity depends on the sample of participants and how representative they are to the population of interest. The sample is made up of participants who undertook the QS Dyslexia Test over a six-month period, and we therefore assume it is a good reflection of the typical users of the tests.

Methods

Correlations and Hypothesis Testing

To identify correlations between reading metrics in the Reading Test and the results from the QS Dyslexia Test, Pearson's correlation coefficients have been calculated when the comparison is between continuous variables (e.g., comparing the reading speed (wpm) between the two tests) and Kendall's rank correlation when the comparison is between ordinal variables (e.g., comparing the reading speed scaled score between the two tests).

The following hypothesis tests are applied throughout:

1. Mann-Whitney U test: this test is applied to compare and test for differences between two distributions (e.g., comparing the distributions of the QS Dyslexia Test dyslexia quotient by the Reading Test reading flag).
2. Kruskal Wallis rank sum test: this test is applied to compare and test for differences between distributions of more than two groups (e.g., comparing the distributions of the reading metrics from the Reading Test by the three dyslexia subgroups: dyslexic, at-risk and non-dyslexic).
3. Fisher's test: this test is applied to test for associations between two categorical variables (e.g., comparing the breakdown of the QS Dyslexia speed of processing results with the Reading Test reading flag).

Optimal cut-offs: Receiver Operating Characteristic (ROC) Curve Analysis

A Receiving Operating Characteristic (ROC) curve[1,2] is a useful tool that in this analysis allows us to identify:

1. The optimal dyslexia quotient cut-off at which to identify whether a participant will be flagged in the Reading Test as having potential processing difficulties, or a specific learning difficulty/dyslexia, that may be hampering their reading fluency.
2. The optimal reading fluency (%) cut-off at which to identify whether a participant is dyslexic or not.

We plot the true positive rate (TPR; or sensitivity) against the false positive rate (FPR; or 1 minus the specificity) for a variety of different classification thresholds based on the QuickScreen dyslexia quotient in (1) and the Reading Test fluency (%) in (2). Each point on the ROC curve represents a different threshold for classification, ranging from all quotients/fluency classified as not being flagged/non-dyslexic in the bottom left-hand corner (i.e., 0% TPR and FPR) and all quotients/fluency classified as being flagged/dyslexics in the top right-hand corner (i.e., 100% TPR and FPR). The best possible predictive model would be one with a 100% TPR and 0% FPR (equivalently 100% sensitivity and specificity), which corresponds with the top left-hand corner of the figure for the ROC curve, though seldom is this achievable. We choose the optimal threshold that maximises the sensitivity and specificity.

[1] https://select-statistics.co.uk/resources/glossary-page/#receiver-operating-characteristic-roc-curve
[2] https://select-statistics.co.uk/blog/classifying-binary-outcomes/

The ROC curve is also a useful indicator of how well the test is able to perform classification. If the ROC curve follows the diagonal y=x line (i.e., TPR = FPR), then any classifications are no better than predicting at random, e.g., by tossing a coin for assigning participants as dyslexic or not. Ideally, we want the curve to lie above this line as this indicates that the test is better than if we were to classify the outcome randomly. We can formalise this by calculating the Area Under the Curve (AUC)[3]. The AUC represents the accuracy of the test in terms of its capacity for discrimination, where 100% is the best possible value (perfect classification), 50% is equivalent to predicting at random and a value of less than 50% is even worse. The AUC estimate can also be interpreted as the probability that the test will assign a higher score to a randomly chosen dyslexic individual than to a randomly chosen non-dyslexic participant. An estimate of the AUC based upon a sample of data, such as the data in this study is, like all estimates, subject to a sampling error. To account for this and express our uncertainty in the estimated AUC due to sampling variability, we also calculated a 95% confidence interval for the AUC.

[3] https://select-statistics.co.uk/resources/glossary-page/#roc-area-curve-auc

Results

Comparison of the QS Dyslexia and Reading Test Results

Consistency of the reading scores between the two tests

To explore the consistency of the reading scores between the two tests, the summary statistics of the distribution of the reading speed (wpm) for each are provided in Table 1 and boxplots of the distributions in Figure 1. These summaries highlight that the distributions are very similar with comparable means and interquartile ranges (the mean reading speed for the QS Dyslexia test is 138.60 wpm and for the Reading Test is 137.40 wpm). Table 1 also includes the summary statistics of the difference between the QS Dyslexia and Reading Tests. Whilst there is some larger differences (with some participants having a difference of up to plus or minus 200 wpm), on average the Dyslexia Test reading speed for a participant is 6.61 wpm more compared to the same result for the Reading Test, with 50% of the participants having a reading speed of 18 wpm less to 28 wpm more in the Reading Test compared to the QS Dyslexia Test.

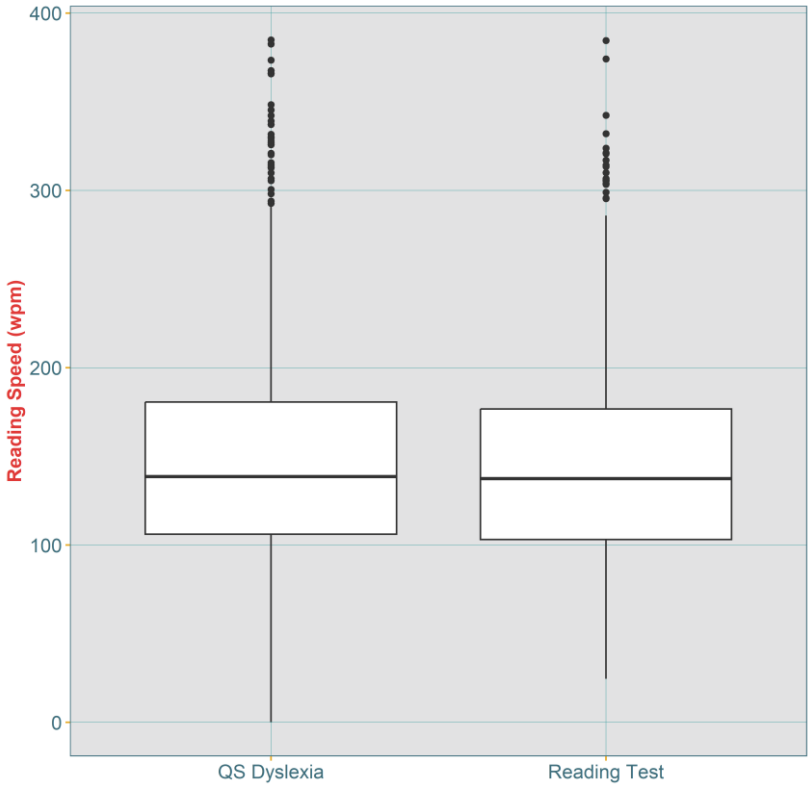

Figure 1: Boxplots of the distribution of the reading speed (wpm) for the QS Dyslexia Test and Reading Test. (The bold horizontal line shows the median value, the box shows the middle 50% of the data, the top of the box shows the upper quartile [75th percentile] and the bottom of the box the lower quartile [25th percentile], the lines extend to the largest and smallest observed values that are no further than 1.5xIQR [interquartile range] from the upper and lower quartiles.)

Reading Speed (wpm)	Minimum	Lower Quartile	Median	Mean	Upper Quartile	Maximum
QS Dyslexia Test	0.10	106.10	138.60	149.50	180.70	384.90
Reading Test	24.60	103.20	137.40	144.00	176.80	384.50
Dyslexia Test – Reading Test	-214.70	-18.15	6.85	6.61	27.70	236.90

Table 1: Summary statistics of the reading speed (wpm) for the QS Dyslexia Test and Reading Test and the difference between the two. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

In Figure 2 we have plotted the reading speeds for each test against one another to explore the relationship between the two. The diagonal pattern in this plot highlights that the two are linearly related to one another, which is confirmed by the Pearson's correlation coefficient of 0.66 which is statistically significant (p-value < 0.001). A correlation coefficient of 1 would represent a complete positive correlation and 0 no correlation. A correlation coefficient of 0.66 indicates good correlation between the two variables. We see from Figure 2 that whilst the data points typically follow the one-to-one diagonal line (the red dashed line), there is some variation in reading speeds between the two tests (which is why the correlation is not closer to 1) and, on average, the QS Dyslexia Test reading speed is typically higher than the Reading Test reading speed (there are more points above the red line than below it).

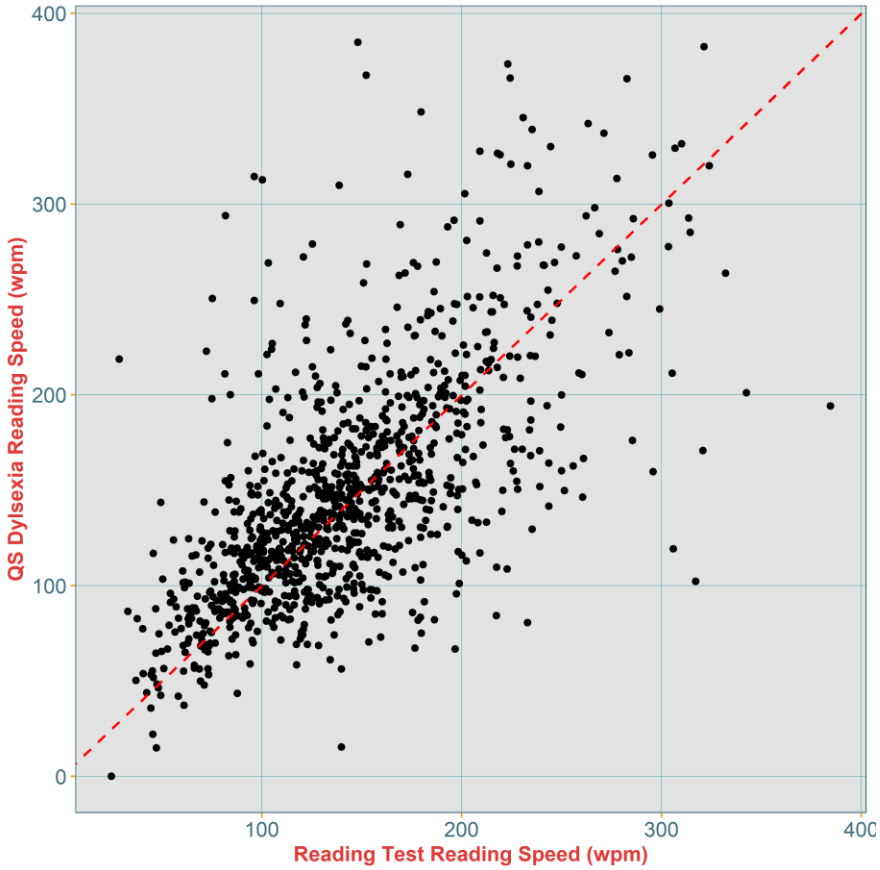

Figure 2: Scatter plot of the QS Dyslexia and Reading Test reading speeds (wpm). The red dashed line represents the one-to-one line which would indicate perfect correlation between the two.

The tests both provide a scaled reading speed score and a frequency table comparing the scaled score between the two tests is provided in Table 2. For a perfect correlation, we would expect to see 100% of participants in each Reading Test scaled score get the same score in the QS Dyslexia Test (colour coded green in the table). This table highlights that for each Reading Test scaled score, most participants also receive the same score in the QS Dyslexia Test (except for score 7, where a higher percentage of participants receive a scaled score of 8 compared to 7 in the QS Dyslexia Test: 45% to 39%). However, it is not a perfect one-to-one mapping, and it is not uncommon for participants to receive a reading scaled score that is one more or less than the other test. Overall, 45.4% participants have a matching reading speed scaled score between the two tests and 79.7% have a scaled score that is either the same or one more or less than the other test. We also note that there is also typically greater variation between the scores for scores that are 12, 14 or 16 (i.e., at the higher end of the scale). The Kendall's rank correlation between the scaled scores is 0.55 which remains moderate to good and is statistically significant (p-value < 0.001).

		Reading Test Reading Speed Scaled Score						
		3	7	8	10	12	14	16
QS Dyslexia Reading Speed Scaled Score	3	15 (42%)	10 (8%)	4 (1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
	7	13 (36%)	51 (39%)	10 (9%)	11 (4%)	2 (2%)	1 (2%)	0 (0%)
	8	7 (19%)	59 (45%)	258 (60%)	79 (30%)	16 (14%)	2 (4%)	2 (6%)
	10	0 (0%)	4 (3%)	90 (21%)	113 (43%)	31 (27%)	13 (28%)	3 (9%)
	12	1 (3%)	4 (3%)	26 (6%)	36 (14%)	35 (31%)	7 (15%)	5 (16%)
	14	0 (0%)	1 (1%)	8 (2%)	19 (7%)	16 (14%)	10 (22%)	6 (19%)
	16	0 (0%)	1 (1%)	5 (1%)	5 (2%)	13 (12%)	13 (28%)	15 (48%)
Total		36 (100%)	130 (100%)	401 (100%)	263 (100%)	103 (100%)	46 (100%)	31 (100%)

Table 2: The breakdown of participants by QS Dyslexia Test and Reading Test reading speed scaled score. Results are given as both frequencies and the percentage across the Reading Test reading speed scaled score. The table is colour coded where green represents a one-to-one relationship in scaled score and yellow, amber and red represent mismatches at an increasing scale.

The QS Dyslexia Test provides an overall result that indicates the potential for dyslexia for a participant based on the categories: None, Borderline, Mild, Moderate and Strong. To explore the association between the Reading Test reading scores and the QS Dyslexia Test overall result, boxplots of the reading scores categorised by the QS overall results are provided in Figure 3 (the summary statistics for these boxplots are also given in the Appendix in Table 29 to Table 31). For all three reading metrics, the distributions reduce as the indication of dyslexia increases. There is strong statistical evidence of a lower average reading speed (wpm), fluency (%) and overall score (%) being associated with evidence of dyslexia (p-value < 0.001 for all three reading metrics using the Kruskal-Wallis rank sum test). The Kendall's rank correlations between reading speed (wpm), fluency (%) and overall score (%) and the QS Dyslexia results are -0.23, -0.44 and -0.38 respectively, illustrating that the strongest relationship exists between reading fluency and the QS dyslexia result. We note that reading fluency is a metric that combines the scores from both silent reading and reading accuracy and represents the most "authentic" reading score.

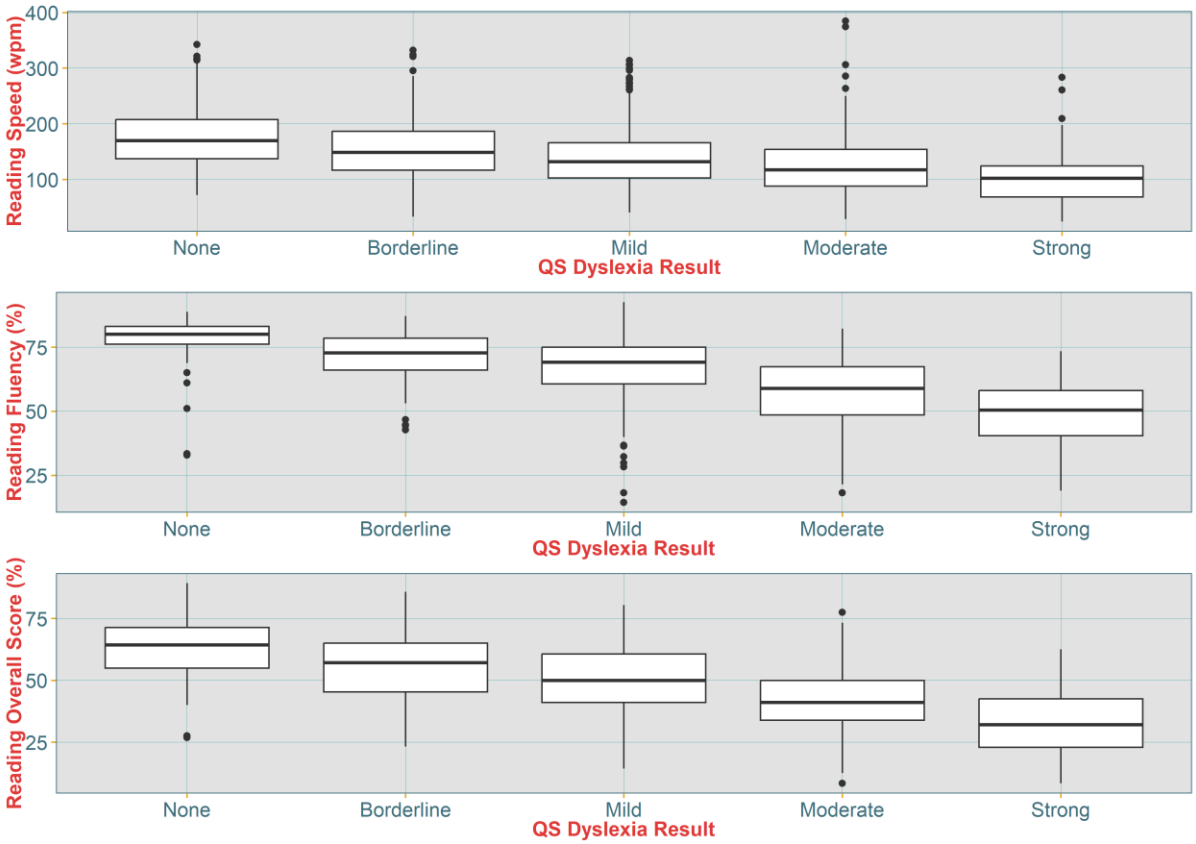

Figure 3: Boxplots of the distribution of the Reading Test's reading speed (wpm), reading fluency (%) and reading overall score (%) by the QS Dyslexia Result. (The bold horizontal line shows the median value, the box shows the middle 50% of the data, the top of the box shows the upper quartile [75th percentile] and the bottom of the box the lower quartile [25th percentile], the lines extend to the largest and smallest observed values that are no further than 1.5xIQR [interquartile range] from the upper and lower quartiles.)

Level of association between the QS Dyslexia quotient/percentile and the Reading Test dyslexia flag

In the Reading Test, if a participant scores low or below average in any or their results (e.g., speed, fluency, comprehension etc.), then they are flagged as having possible processing difficulties, or a specific learning disability/dyslexia. To explore the association between the Reading Test dyslexia flag and the QS dyslexia percentile/quotient results, boxplots of the percentiles and quotients categorised by the dyslexia flag are provided in Figure 4 and their summary statistics in Table 3. In both cases, the Mann Whitney U test indicates that there is strong statistical evidence of a higher average dyslexia quotient and percentile being associated with those who have been identified as being possibly dyslexic in the Reading Test than those who have not (p-value < 0.001). The median dyslexic quotient for those who have been flagged in the reading test as being possibly dyslexic is 4.00 compared to 5.50 for those that have not been flagged, whilst the median dyslexic percentile is 0.62 compared to 0.37.

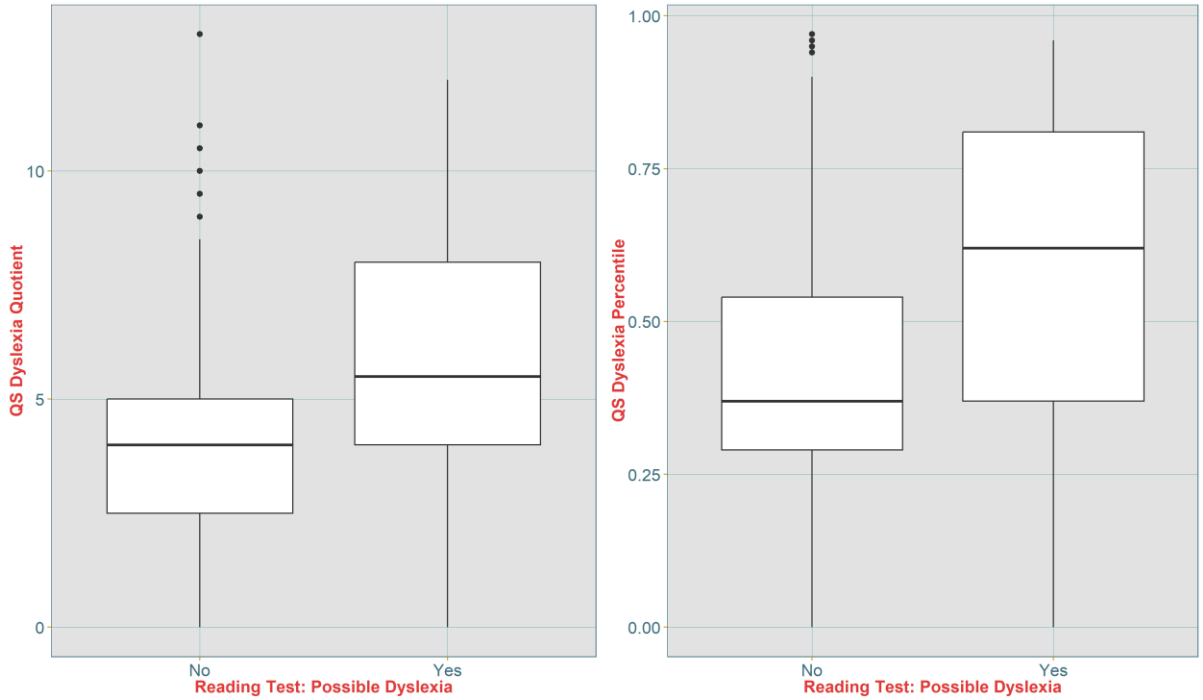

Figure 4: Boxplots of the distribution of the QS Dyslexia Test's quotient and percentile results by the Reading Test dyslexia flag. (The bold horizontal line shows the median value, the box shows the middle 50% of the data, the top of the box shows the upper quartile [75th percentile] and the bottom of the box the lower quartile [25th percentile], the lines extend to the largest and smallest observed values that are no further than 1.5xIQR [interquartile range] from the upper and lower quartiles.)

QS Test	Reading Test Dyslexia Flag	Minimum	Lower Quartile	Median	Mean	Upper Quartile	Maximum
Dyslexia Quotient	Yes	0.00	4.00	5.50	5.92	8.00	12.00
	No	0.00	2.50	4.00	3.88	5.00	13.00
Dyslexia Percentile	Yes	0.00	0.37	0.62	0.60	0.81	0.96
	No	0.00	0.29	0.37	0.41	0.54	0.97

Table 3: Summary statistics of the QS Dyslexia Test dyslexia quotient and percentile split by the Reading Test dyslexia flag. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

Optimal QS Dyslexia percentile that predicts Reading Test dyslexia flag

The objective of this analysis is to identify the optimal QS Dyslexia percentile that predicts whether a participant will also have reading difficulties (as defined by the Reading Test dyslexia flag). To do this we have carried out a ROC analysis and plotted the ROC curve in Figure 5. The ROC curve plots the proportion of false positive vs. true positives for each QS dyslexia percentile. The optimal cut-off point is chosen to be the one that minimises the false positives (incorrectly identifying a participant as having reading difficulties) and maximises the true positives (correctly identifying a participant has having reading difficulties).

The ROC curve Area Under the Curve (AUC) is estimated to be 72.3% with a 95% confidence interval of 69.20% to 75.40%. Given that the AUC of a perfect model that predicts all participants correctly

would be 100%, this illustrates that the QS dyslexia percentile has a moderate predictive capacity for the Reading Test dyslexia flag.

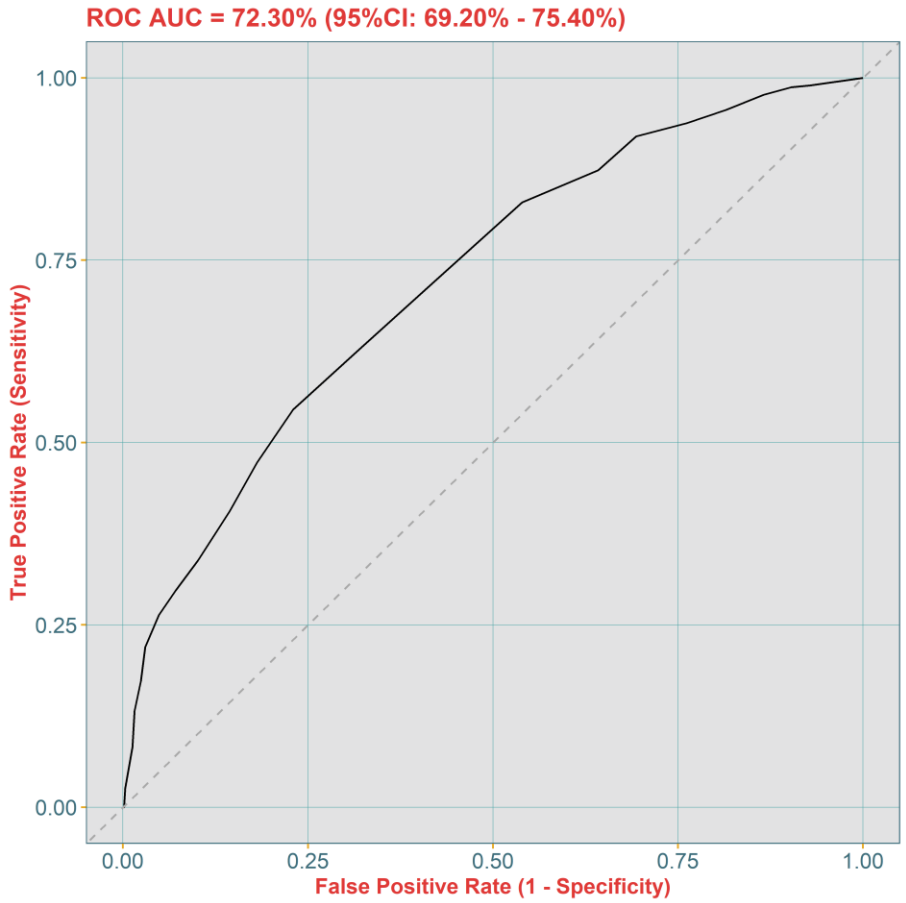

Figure 5: ROC Curve for the Reading Test reading flag based on the QS dyslexia percentile.

The optimal dyslexia percentile cut-off associated with predicting the Reading Test dyslexia flag based on the ROC curve is 49.5%. This means that QS Dyslexia Test participants who obtain a dyslexia percentile greater than 49.5% should be considered as likely to have reading difficulties (i.e., we would expect them to be flagged in the Reading Test if they also took this test). Conversely, those QS Dyslexia Test participants who obtain a dyslexia percentile less than or equal to 49.5% should be considered as unlikely to have reading difficulties (i.e., we would expect them not to be flagged in the Reading Test if they also took this test).

Whilst this is the optimal threshold, we know that it will not perfectly predict whether a participant will be flagged in the Reading Test as having reading difficulties. To explore the accuracy of the threshold within the sample, we calculate the number of participants whose QS Test Dyslexia Percentile is greater than 49.5% and compare this to the Reading Test dyslexia flag (Table 4). A Chi-square test on this data finds strong statistical evidence (p-value < 0.001) of an association between the Reading Test dyslexic flag and the participants who have been grouped according to the QS dyslexia percentile cut-off. We find that the Reading Test dyslexia flag is correctly predicted for 719 of the 1088 participants (66.1%) in our sample based on their QS Test Dyslexia Percentile and 369 are incorrectly predicted (33.9%).

Reading Test Dyslexia Flag	QS Test: Dyslexia Percentile ≤ 49.5%	QS Test: Dyslexia Percentile > 49.5%	Total
No	475	226	701 (64.4%)
Yes	143	244	387 (35.6%)
Total	618 (56.8%)	470 (43.2%)	1088 (100%)

Table 4: Cross-tabulation of the Reading Test dyslexia flag versus the QS percentile based on the optimal threshold.

To explore the accuracy further, in Table 5 we calculate:

1. The sample specificity: the proportion of participants who are not flagged in the Reading Test and who are below the optimal QS dyslexia percentile cut off (the true negatives).
2. The sample sensitivity: the proportion of participants who are flagged in the Reading Test and are above the QS dyslexia percentile cut off (the true positives).

We find that 67.76% of participants are correctly predicted as not being flagged in the Reading Test based on their QS Dyslexia Percentile (the true negatives) and 63.05% of are correctly predicted as being flagged in the Reading Test based on their QS Dyslexia Percentile (the true positives).

Reading Test Dyslexia Flag	QS Test: Dyslexia Percentile ≤ 49.5%	QS Test: Dyslexia Percentile > 49.5%
No	67.76%	32.23%
Yes	36.95%	63.05%

Table 5: Raw sample specificity (dyslexia flag: no row) and sensitivity (dyslexia flag: yes) values for the QS percentile negative and positive results, based on the optimal cut off of 49.5%.

Overall, we find that using the QS Dyslexia test Dyslexia Percentile to predict whether a participant has reading difficulties or not (i.e., will or will not be flagged in the Reading Test) results in a prediction that is correct on approximately two-thirds of occasions based on the current sample. It is not surprising that the QS Dyslexia Percentile cannot predict the Reading Test flag perfectly. We know that it is possible for someone to not suffer from Dyslexia and to have reading difficulties (i.e., a low Dyslexia Percentile but flagged in the Reading Test) and, conversely, for someone with dyslexia not to have reading difficulties (i.e., a high Dyslexia Percentile but not flagged in the Reading Test). Therefore, the QS Dyslexia Test dyslexia percentile can be used as an initial screener of reading difficulties if the overall accuracy of 66.1% is acceptable.

Comparison of the QS speed of processing and Reading Test dyslexia flag

The breakdown of the QS speed of processing by Reading Test dyslexia flag is given in Table 6. This table highlights that 92.7% of those who have no difficulties in their speed of processing based on the QS Dyslexia Test have not been flagged as being possibly dyslexic in the Reading Test. Conversely, 67.5% of those who have difficulties are flagged as being possibly dyslexic in the Reading Test. There is strong statistical evidence that that the Reading Test flag is associated with speed of processing as defined by the QS Dyslexia Test (p-value < 0.001 based on the Fisher's test). We note that dyslexia can range in severity from person to person and that symptoms of dyslexia vary between people. Specifically, we know that not all dyslexics have reading difficulties (Fink, 1998) and therefore it is not surprising that 32.5% participants who have been flagged in the QS Dyslexia Test

as having "difficulties" in Speed of Processing have not been flagged in the Reading Test as having reading difficulties.

Reading Test Dyslexia Flag	QS Dyslexia Test Speed of Processing		
	No Difficulties	Average	Difficulties
Yes	13 (7.3%)	160 (26.7%)	214 (67.5%)
No	165 (92.7%)	433 (73.0%)	103 (32.5%)

Table 6: The breakdown of participants by Reading Test dyslexia flag and their QS Dyslexia Test speed of processing result.

Reading Test: Exploration by Dyslexic group

The above analysis focussed on comparing the results between the QS Dyslexia Test and Reading Test to explore consistency between the results. In this section, we explore the Reading Test result by the subgroups of participants based on whether they have been identified as dyslexic, at-risk or non-dyslexic.

In Table 7 and Table 8 we provide the summary statistics for reading speed (wpm) split by dyslexia group for the Reading Test and the QS Dyslexia Test respectively. The average reading speed for a participant with dyslexia in the Reading Test is 127.75 wpm compared to 121.75 wpm in the QS Dyslexia Test. The average reading speed for a participant in the non-dyslexic group in the Reading Test is 156.20 wpm compared to 169.05 wpm in the QS Dyslexia Test.

Reading Test	Min	Lower Quartile	Median	Mean	Upper Quartile	Max	N
Dyslexic	24.60	94.05	136.81	127.75	169.08	384.50	184
At Risk	28.60	102.35	141.13	136.10	173.20	374.20	715
Non-Dyslexic	32.90	120.62	162.25	156.20	193.00	332.00	184

Table 7: Summary statistics of the Reading Test reading speed (wpm) by the dyslexic subgroups. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

QS Dyslexia Test	Min	Lower Quartile	Median	Mean	Upper Quartile	Max	N
Dyslexic	0.100	94.42	132.12	121.75	161.25	312.80	176
At Risk	15.00	105.30	146.24	136.60	173.60	367.60	699
Non-Dyslexic	66.40	134.38	179.68	169.05	220.90	384.90	178

Table 8: Summary statistics of the QS Dyslexia Test reading speed (wpm) by the dyslexic subgroups. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

The breakdown of the Reading Test dyslexia flag by dyslexia subgroups is provided in Table 9. In total, 35.6% of the participants received a flag in the Reading Test indicating possible dyslexia. When we split this by the three groups, 25.5% of non-dyslexics are flagged in the Reading Test, 34.1% of the at-risk and 51.4% of the dyslexic group. There is strong evidence that the dyslexic flag is associated with the dyslexia subgroups (p-value < 0.001 based on the Fisher's test); a greater proportion of the dyslexia group are flagged in the Reading Test than the non-dyslexic group.

Reading Test Dyslexia Flag	Non-Dyslexic	At-Risk	Dyslexic	Totals
No	137 (74.5%)	474 (65.9%)	90 (48.5%)	701 (64.4%)
Yes	47 (25.5%)	245 (34.1%)	95 (51.4%)	387 (35.6%)
Totals	184 (100%)	719 (100%)	185 (100%)	1088 (100%)

Table 9: The breakdown of participants by Reading Test dyslexia flag and by dyslexia subgroup.

We note that 25.5% of non-dyslexics are flagged in the Reading Test as having possible processing difficulties, or a specific learning disability/dyslexia based on their reading ability. It is important to view this result in the context of the non-dyslexic sample who have not been formally assessed for dyslexia (and therefore could feasibly be undiagnosed dyslexic and placed in the wrong dyslexia subgroup) and that it is also possible for someone to not have dyslexia, but to have reading difficulties (i.e., it would be accurate that some non-dyslexics are flagged in the Reading Test as having reading difficulties). Summary statistics of each individual reading measure that is provided by the Reading Test for this subgroup (the non-dyslexic group who were flagged in the Reading Test) are provided in the Appendix in Table 32. The objective was to explore further whether this subgroup had any notably different results. Reviewing the results, we see that on average this subgroup typically scores low for all the reading metrics (consistent with the average results we see for the dyslexic group, see Table 11 to Table 18 below).

Conversely, 48.5% of dyslexics have not been flagged in the Reading Test as having possible processing difficulties, or a specific learning disability/dyslexia based on their reading ability. It is perhaps not surprising given the sample that only approximately 50% of participants are flagged in the Reading Test. Firstly, we know that not all dyslexics have reading difficulties. Secondly, as discussed above, the dyslexic group in the sample is made up primarily of those who are currently in higher education or graduates in professional jobs. These participants are likely to have attained satisfactory or good levels of literacy and/or reading to reach higher education (Brèthes et al (2022)) therefore we would not expect all these samples to have low or below average reading results in the Reading Test.

The same breakdown is given in Table 10 but only for those participants whose first language is not English. For this group, we see a slightly different pattern. For the non-dyslexic group, a greater proportion are flagged in the Reading Test (45.5% compared to 25.5% in the full cohort). For the dyslexic group, we also see a greater proportion flagged in the Reading Test (86.7% compared to 51.4% in the full cohort). This result should be taken as indicative only as the sample size is small; only 15 participants are dyslexic and have English as a second language.

Reading Test Dyslexia Flag	Non-Dyslexic	At-Risk	Dyslexic	Totals
No	18 (54.5%)	30 (48.4%)	2 (13.3%)	50 (45.5%)
Yes	15 (45.5%)	32 (51.6%)	13 (86.7%)	60 (54.5%)
Totals	33 (100%)	62 (100%)	15 (100%)	110 (100%)

Table 10: The breakdown of participants whose English is their second language by Reading Test dyslexia flag and by dyslexia subgroup.

To explore how the reading test results vary by dyslexia group, summary statistics are provided in Table 11 to Table 18 and boxplots in Figure 6. Each table includes a p-value for a test of association between the reading metric and the dyslexic groups based on the Kruskal-Wallis rank sum test. In all

variables, we find that there is an association between the metric and the dyslexic groups except for speed of processing (p-value = 0.092). For all the remaining variables, the mean value for each metric is largest for the non-dyslexic group, followed by the at-risk group and then the smallest for the dyslexic group. This relationship does not hold for speed of processing; however, this is not surprising.

In the Reading Test, it is likely that the speed of processing result is not accurate since some participants may rush the test (i.e., if a participant is not sure of the answer, they can click on any answer and move on). The speed of processing measure from the QS Dyslexia Test will be a more accurate measure since a participant is timed for each test and requires continuous engagement and participation throughout. It is not surprising, therefore, that when analysing the speed of processing from the QS Dyslexia test, we see an association with the reading test flag (those who are identified as having speed of processing difficulties in the QS Dyslexia Test are more likely to be flagged in the reading test).

Overall, we find that the data does support the hypothesis that those with dyslexia have on average, poorer reading speed, accuracy and comprehension. The data does not support the hypothesis that those with dyslexia have slower speeds of processing based on the Reading Test results, but this is due to the measure not accurately measuring speed of processing. We know that speed of processing is more accurately measures in the QS Dyslexia Test and from previous work that difficulties in speed of processing is associated with dyslexia.

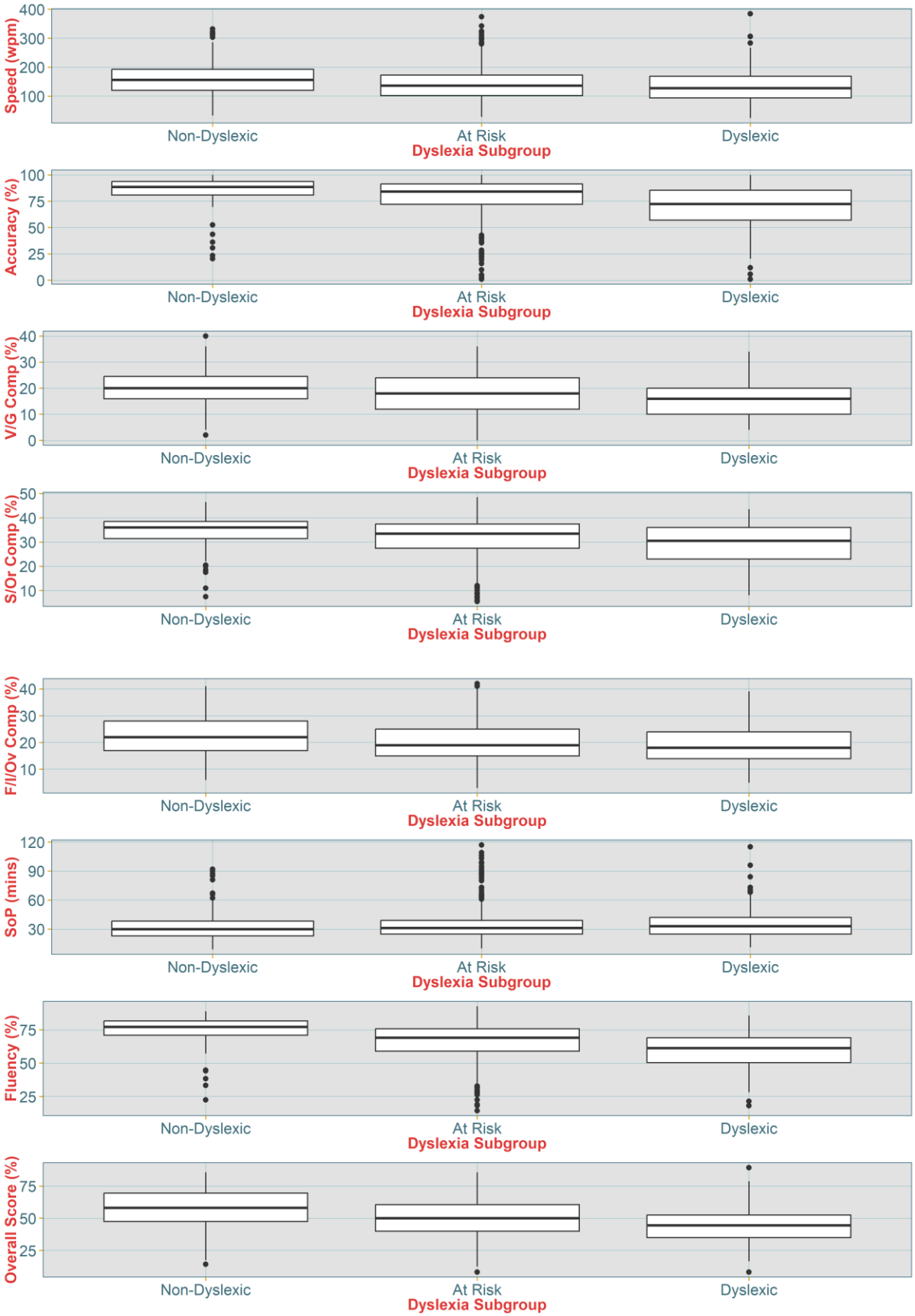

Figure 6: Boxplots of the distribution of the Reading Test results by dyslexia group.

Reading Speed (wpm)	Min	Lower Quartile	Median	Mean	Upper Quartile	Max	N	p-value
Dyslexic	24.60	94.05	136.81	127.75	169.08	384.50	184	<0.001
At Risk	28.60	102.35	141.13	136.10	173.20	374.20	715	
Non-Dyslexic	32.90	120.62	162.25	156.20	193.00	332.00	184	

Table 11: Summary statistics of the Reading Test reading speed (wpm) by the dyslexic subgroups. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

Reading Accuracy (%)	Min	Lower Quartile	Median	Mean	Upper Quartile	Max	N	p-value
Dyslexic	1.00	57.10	68.14	72.40	85.40	100.00	133	<0.001
At Risk	1.00	72.25	77.60	84.10	91.50	100.00	487	
Non-Dyslexic	20.30	80.90	84.08	88.60	93.70	100.00	97	

Table 12: Summary statistics of the Reading Test reading accuracy (%) by the dyslexic subgroups. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

V/G Comp (%)	Min	Lower Quartile	Median	Mean	Upper Quartile	Max	N	p-value
Dyslexic	4.00	10.00	15.72	16.00	20.00	34.00	185	<0.001
At Risk	0.00	12.00	17.89	18.00	24.00	36.00	718	
Non-Dyslexic	2.00	16.00	19.95	20.00	24.50	40.00	187	

Table 13: Summary statistics of the Reading Test V/G Comprehension (%) by the dyslexic subgroups. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

S/Or Comp (%)	Min	Lower Quartile	Median	Mean	Upper Quartile	Max	N	p-value
Dyslexic	8.00	23.00	29.18	30.50	36.00	43.50	185	<0.001
At Risk	5.50	27.50	31.88	33.50	37.50	48.50	718	
Non-Dyslexic	7.50	31.50	34.40	36.00	38.50	46.50	187	

Table 14: Summary statistics of the Reading Test S/Or Comprehension (%) by the dyslexic subgroups. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

F/I/Ov Comp (%)	Min	Lower Quartile	Median	Mean	Upper Quartile	Max	N	p-value
Dyslexic	5.00	14.00	18.85	18.00	24.00	39.00	185	<0.001
At Risk	3.00	15.00	19.89	19.00	25.00	42.00	718	
Non-Dyslexic	6.00	17.00	22.62	22.00	28.00	41.00	187	

Table 15: Summary statistics of the Reading Test F/I/Ov Comprehension (%) by the dyslexic subgroups. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

Speed of Processing	Min	Lower Quartile	Median	Mean	Upper Quartile	Max	N	p-value
Dyslexic	11.00	25.00	35.46	33.00	42.00	115.00	180	0.092
At Risk	10.00	25.00	34.49	31.00	39.00	117.00	709	
Non-Dyslexic	9.00	23.00	33.11	30.00	38.25	92.00	180	

Table 16: Summary statistics of the Reading Test speed of processing by the dyslexic subgroups. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

Reading Fluency	Min	Lower Quartile	Median	Mean	Upper Quartile	Max	N	p-value
Dyslexic	18.20	50.40	58.89	61.30	69.00	85.60	133	<0.001
At Risk	14.40	59.00	66.16	69.10	75.75	92.60	487	
Non-Dyslexic	22.50	70.90	73.91	77.10	81.70	88.80	97	

Table 17: Summary statistics of the Reading Test reading fluency by the dyslexic subgroups. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

Reading Overall Score	Min	Lower Quartile	Median	Mean	Upper Quartile	Max	N	p-value
Dyslexic	8.30	35.00	44.39	44.60	52.50	89.30	180	<0.001
At Risk	8.30	40.00	50.49	50.00	60.70	85.70	709	
Non-Dyslexic	14.30	47.50	57.54	58.20	69.60	85.70	180	

Table 18: Summary statistics of the Reading Test reading overall score by the dyslexic subgroups. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

Reading Test: Exploration by English as a First or Second Language

To explore the differences in the Reading Test metrics by whether a participants first language is English, summary statistics of each reading metric are provided in Table 19 to Table 26 and boxplots in Figure 7 split by English as a first language. The Kruskal-Wallis rank sum test is applied to each metric. In these statistics, we find that there is statistical evidence of a difference in the reading metrics between those whose English is their first language and second language. The results are, on average, lower for those whose English is their second language. We do not find evidence of a difference in vocabulary and general knowledge comprehension (p-value = 0.795) and factual, inference and overview comprehension (p-value = 0.723). It is interesting that there is a difference in speed of processing with participants whose English is their second language taking longer on average (mean 39 minutes compared to 30 minutes) which may be due to these participants being more likely to work their way fully through the reading test without rushing compared to those who have English as a first language.

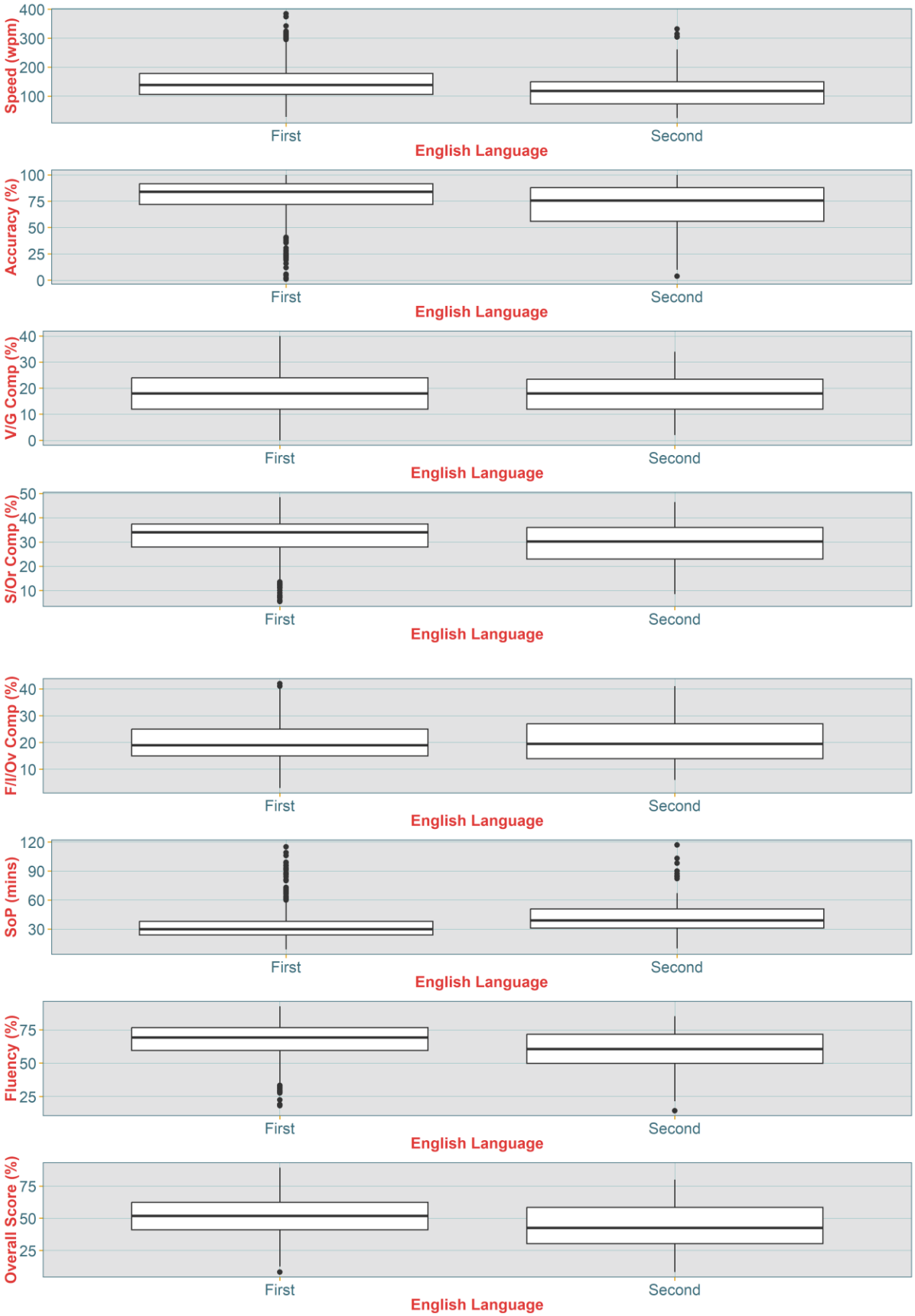

Figure 7: Boxplots of the distribution of the Reading Test results by English language (i.e., first or second).

Reading Speed (wpm)	Min	Lower Quartile	Median	Mean	Upper Quartile	Max	N	p-value
English 1st Language	28.60	106.55	146.34	138.90	178.80	384.50	971	<0.001
English 2nd Language	24.60	73.72	124.00	118.20	150.12	332.00	110	

Table 19: Summary statistics of the Reading Test reading speed (wpm) by English as a first language. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

Reading Accuracy (%)	Min	Lower Quartile	Median	Mean	Upper Quartile	Max	N	p-value
English 1st Language	1.00	71.95	77.68	84.00	91.55	100.00	635	0.001
English 2nd Language	3.70	56.00	69.17	75.70	87.80	100.00	81	

Table 20: Summary statistics of the Reading Test reading accuracy (%) by English as a first language. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

V/G Comp (%)	Min	Lower Quartile	Median	Mean	Upper Quartile	Max	N	p-value
English 1st Language	0.00	12.00	17.90	18.00	24.00	40.00	976	0.795
English 2nd Language	2.00	12.00	17.62	18.00	23.50	34.00	110	

Table 21: Summary statistics of the Reading Test V/G Comprehension (%) by English as a first language. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

S/Or Comp (%)	Min	Lower Quartile	Median	Mean	Upper Quartile	Max	N	p-value
English 1st Language	5.50	28.00	32.10	34.00	37.50	48.50	976	0.001
English 2nd Language	8.50	23.00	29.68	30.25	36.00	46.50	110	

Table 22: Summary statistics of the Reading Test S/Or Comprehension (%) by English as a first language. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

F/I/Ov Comp (%)	Min	Lower Quartile	Median	Mean	Upper Quartile	Max	N	p-value
English 1st Language	3.00	15.00	20.12	19.00	25.00	42.00	976	0.723
English 2nd Language	6.00	14.00	20.72	19.50	27.00	41.00	110	

Table 23: Summary statistics of the Reading Test F/I/Ov Comprehension (%) by English as a first language. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

Speed of Processing	Min	Lower Quartile	Median	Mean	Upper Quartile	Max	Missing	p-value
English 1st Language	9.00	24.00	33.43	30.00	38.00	115.00	966	<0.001
English 2nd Language	10.00	31.00	43.94	39.00	51.00	117.00	101	

Table 24: Summary statistics of the Reading Test speed of processing by English as a first language. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

Reading Fluency	Min	Lower Quartile	Median	Mean	Upper Quartile	Max	N	p-value
English 1st Language	18.20	59.50	66.73	69.30	76.70	92.60	635	<0.001
English 2nd Language	14.40	49.90	59.11	60.60	71.60	85.10	81	

Table 25: Summary statistics of the Reading Test reading fluency by English as a first language. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

Reading Overall Score	Min	Lower Quartile	Median	Mean	Upper Quartile	Max	N	p-value
English 1st Language	8.30	41.10	51.47	51.80	62.50	89.30	976	<0.001
English 2nd Language	8.30	30.40	43.59	42.50	58.55	80.00	110	

Table 26: Summary statistics of the Reading Test reading overall score by English as a first language. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

Reading Test: Optimal Reading Fluency (%) that Predicts Dyslexia

The objective of this analysis is to identify the optimal reading fluency (%) from the Reading Test that predicts whether a participant is dyslexic or not. To do this we have carried out a ROC analysis on the subset of participants who are defined as dyslexic and non-dyslexic (i.e., removing those participants who are "at risk") and plotted the ROC curve in Figure 8. The ROC curve plots the proportion of false positive vs. true positives for each increasing reading fluency score point. The optimal cut-off point is chosen to be the one that minimises the false positives (incorrectly identifying a participant as having reading difficulties) and maximises the true positives (correctly identifying a participant has having reading difficulties).

The ROC curve Area Under the Curve (AUC) is estimated to be 82.4% with a 95% confidence interval of 76.69% to 88.15%. Given that the AUC of a perfect model that predicts all participants correctly would be 100%, this illustrates that reading fluency has a good predictive capacity for identifying whether a participant is dyslexic or not.

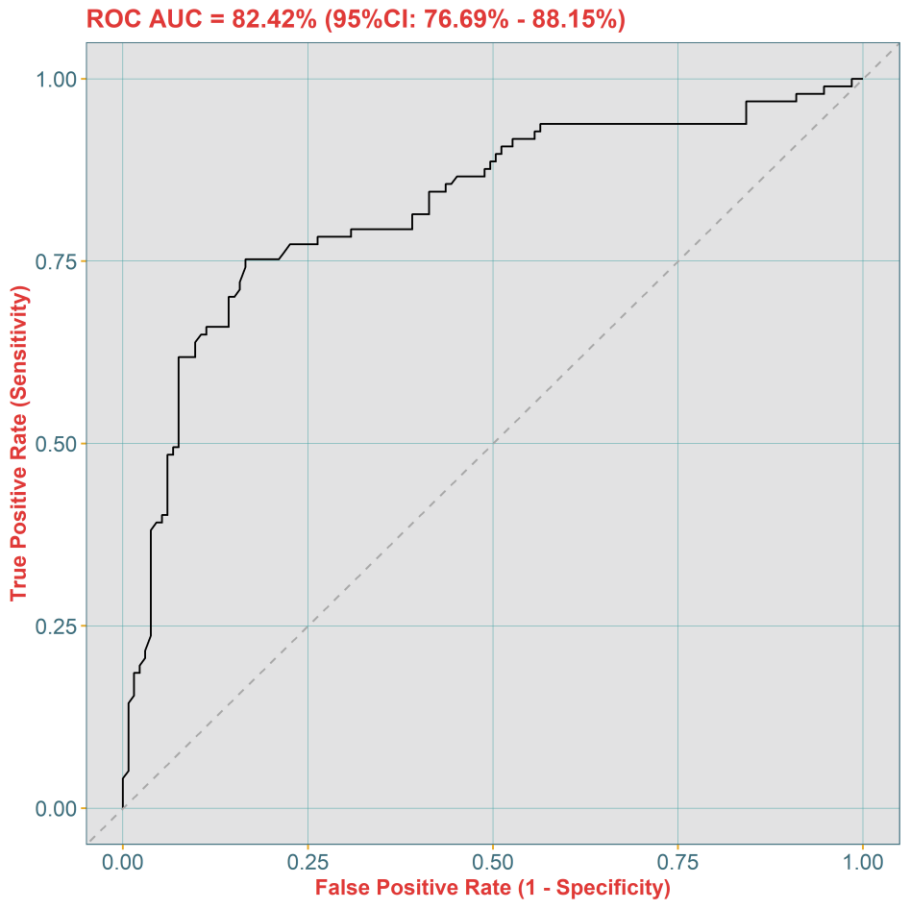

Figure 8: ROC Curve for the Reading Test reading flag based on the QS dyslexia percentile.

The optimal reading fluency cut-off associated with predicting whether a participant is dyslexic based on the ROC curve is 70.7%. This means that Reading Test participants who obtain a reading fluency of less than or equal to 70.7% should be considered as likely to be dyslexic. Conversely, those Reading Test participants who obtain a reading fluency of greater than 70.7% should be considered as unlikely to be dyslexic.

Whilst this is the optimal threshold, we know that it will not perfectly predict whether a participant is dyslexic. To explore the accuracy of the threshold within the sample, we calculate the number of participants whose Reading Test is greater than 70.7% and compare this to whether they are dyslexic (Table 27). A Chi-square test on this data finds strong statistical evidence (p-value < 0.001) of an association between dyslexia and the participants who have been grouped according to the reading fluency cut-off. We find that dyslexia is correctly predicted for 184 of the 230 participants (80.0%) in our sample based on their reading fluency and 46 are incorrectly predicted (20.0%).

Dyslexia Group	Reading Fluency > 70.7%	Reading Fluency ≤ 70.7%	Total
Non-Dyslexic	73	24	97 (42.2%)
Dyslexic	22	111	133 (57.8%)
Total	95 (41.3%)	135 (58.7%)	230 (100%)

Table 27: Cross-tabulation of dyslexia versus the reading fluency based on the optimal threshold.

To explore the accuracy further, in Table 5 we calculate:

1. The sample specificity: the proportion of participants who are dyslexic and who are above the optimal reading fluency cut off (the true negatives).
2. The sample sensitivity: the proportion of participants who are dyslexics and are less than or equal to the reading fluency cut off (the true positives).

We find that 75.23% of participants are correctly predicted as not being dyslexic based on their reading fluency (the true negatives) and 83.46% of are correctly predicted as being dyslexic based on their reading fluency (the true positives).

Dyslexia Group	Reading Fluency > 70.7%	Reading Fluency ≤ 70.7%
Non-Dyslexic	75.23%	24.77%
Dyslexic	16.54%	83.46%

Table 28: Raw sample specificity (non-dyslexic) and sensitivity (dyslexic) values for the reading fluency negative and positive results, based on the optimal cut off of 70.7%.

Overall, we find that using the Reading Test reading fluency result to predict whether a participant is dyslexic or not results in a prediction that is correct on approximately 80% of occasions based on the current sample and may be a useful initial screener of dyslexia.

Conclusions and Next Steps

A good level of consistency was found between the reading results of both the QS Dyslexia Test and the recently added Reading Test with a positive correlation between reading speed (wpm) of 0.66. We found evidence of an association between the reading scores in the Reading Test and the overall result from the QS Dyslexia Test with the average reading score reducing the greater the strength of dyslexia. Both the QS Dyslexia Test dyslexia quotient and percentile are higher on average for those participants who are flagged in the Reading Test as having possible processing difficulties or specific learning difficulties/dyslexia compared to those who are not flagged.

There was an association between the Reading Test flag and the dyslexic subgroups with 25.5% of non-dyslexics flagged in the Reading Test compared to 51.4% of the dyslexic group. These results should be viewed within the context of the following points:

1. Participants in the non-dyslexic group have not been formally assessed for dyslexia (and therefore some may feasibly be undiagnosed dyslexic) and it is also possible that some non-dyslexics have reading difficulties.
2. Research shows that with the right strategies people with dyslexia can achieve high levels of literacy (see Brèthes et al (2022), Fink (1998)). Therefore, with sustained application and use of study skills techniques, individuals may become well compensated or borderline in their dyslexia symptoms and have attained satisfactory levels of reading abilities. Based on the results, in this sample, just over 50% of dyslexic users of the QS Dyslexia and Reading test are fluent readers.

There is statistical evidence of a lower average reading speed (wpm), fluency (%) and accuracy (%) being associated with evidence of dyslexia. Overall, the data from the Reading Test does support the hypothesis that those with dyslexia, experience, on average, poorer reading speed, accuracy and comprehension.

The optimal reading fluency cut-off to classify a participant as being dyslexic is 70.7% (which corresponds with mid average reading performance). This means that Reading Test participants who obtain a reading fluency of less than or equal to 70.7% should be considered as likely to be dyslexic. The reading fluency has fairly good predictive capacity for indicating whether a participant will be flagged up in the reading test summary and could be considered as a useful initial screener of dyslexia; applying the cut-off to the sample, we found an accuracy of 80%, a sensitivity of 83.46% and a specificity of 75.23%.

Future studies could explore the variations between higher achieving dyslexic adults at university and in post graduate professions and those who have not had the benefit of further and higher education. Does the QS test also identify other abilities/talents that are not directly dependent on literacy, but which are as relevant for specific work outcomes as levels of literacy. It may also be worth considering further exploration of the family history of dyslexia flag. In this study, 57% of the dyslexic group have flagged a family history, which is a smaller than expected proportion compared to previous studies (Schumacher et al (2007)).

References

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Appendix

Reading Speed (wpm)		Min	Lower Quartile	Median	Mean	Upper Quartile	Max	Missing	p-value
QS Dyslexia Result	None	72.20	137.65	175.59	169.70	207.75	342.40	0	<0.001
	Borderline	32.90	117.00	154.84	148.90	186.70	332.00	1	
	Mild	40.30	102.85	139.60	132.20	165.90	313.50	2	
	Moderate	28.60	88.25	128.50	117.30	154.30	384.50	2	
	Strong	24.60	68.70	109.11	102.50	124.40	283.60	0	

Table 29: Summary statistics of the Reading Test reading speed (wpm) by the QS Dyslexia Test result. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

Reading Fluency (%)		Min	Lower Quartile	Median	Mean	Upper Quartile	Max	Missing	p-value
QS Dyslexia Result	None	32.80	76.15	77.97	80.05	83.18	88.80	65	<0.001
	Borderline	42.70	66.12	71.60	72.80	78.53	87.10	94	
	Mild	14.40	60.65	66.85	69.10	75.00	92.60	121	
	Moderate	18.20	48.60	57.29	58.90	67.40	82.20	80	
	Strong	19.00	40.50	49.48	50.50	58.07	73.40	11	

Table 30: Summary statistics of the Reading Test reading fluency (%) by the QS Dyslexia Test result. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

Reading Overall Score (%)		Min	Lower Quartile	Median	Mean	Upper Quartile	Max	Missing	p-value
QS Dyslexia Result	None	26.80	55.00	62.60	64.30	71.40	89.30	0	<0.001
	Borderline	23.20	45.35	56.45	57.10	65.00	85.70	0	
	Mild	14.30	41.10	50.56	50.00	60.70	80.40	0	
	Moderate	8.30	33.90	41.59	41.10	50.00	77.50	0	
	Strong	8.30	22.90	33.76	32.10	42.50	62.50	0	

Table 31: Summary statistics of the Reading Test reading overall score (%) by the QS Dyslexia Test result. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).

Reading Test Measures	Min	Lower Quartile	Median	Mean	Upper Quartile	Max	Missing
Reading Speed (wpm)	32.90	79.45	130.41	116.6	156.25	332.00	0
Reading Accuracy (%)	20.30	50.25	69.78	78.65	87.35	97.70	23
Reading Fluency (%)	22.50	55.65	61.86	64.40	74.48	84.20	23
F/I/Ov Comprehension (%)	6.00	12.00	18.51	18.00	23.50	41.00	0
V/G Comprehension (%)	2.00	8.00	15.36	16.00	22.00	32.00	0
S/Or Comprehension (%)	7.50	23.75	29.73	32.00	36.00	45.00	0
Speed of Processing (min)	9.00	28.00	44.33	44.00	58.00	92.00	2
Reading Overall Score (%)	14.3	34.45	42.12	40.60	50.90	65.00	0

Table 32: Summary statistics of the Reading Test measures for the subgroup of non-dyslexics who have been flagged in the Reading Test as possibly having dyslexia. These summaries include the minimum and maximum values, the mean, the median (the middle point of the data), the lower quartile (the 25th percentile) and the upper quartile (the 75th percentile).