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Assessment of the Diagnostic Accuracy of the QuickScreen Dyslexia Test 2024

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Executive Summary

Background

QuickScreen is an adult computerised screening test that assesses and delivers an indication of possible dyslexia without the need for users to undergo a costly professional assessment by an educational or occupational psychologist. In this study, Select provides an independent analysis of the diagnostic accuracy of QuickScreen based on the test's dyslexia quotient (degree of consistency with a dyslexia profile, based on established research).

The data were provided by Pico Educational Systems and included all candidates who, between 1st February 2024 and 21st July 2024, undertook a 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 time 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" and were explored in a separate exploratory analysis in the dyslexic group. 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.

Estimates of the proportion of the population who have dyslexia vary from between 4 and 20% which is a wide margin. Within that, the challenges faced by dyslexic people range from mild to very severe. The assessments in the QuickScreen Dyslexia screener are designed to identify 'functional' dyslexia (i.e. people who are experiencing difficulties or who have a mismatch in the different qualities assessed). Adults, having completed their compulsory education, and particularly those at the more mild end of the dyslexia spectrum, are likely to be well compensated. Given this (which is discussed further in the report), the results of our accuracy assessment may be conservative (i.e. the reported results may underestimate the true performance of the QuickScreen Dyslexia test in practice).

Headline Results

An essential step in the evaluation process of any diagnostic/screening test is to assess its accuracy. The overall accuracy of a diagnostic test indicates how good it is at correctly identifying people with and without the condition in question. It is the probability that someone's status is correctly identified by the test. (Note that the accuracy of a diagnostic test does depend on the prevalence of the underlying condition being diagnosed. Rare conditions are more difficult to detect accurately.)

- When the prevalence of dyslexia is estimated to be 10% (a reasonable mid-point between the estimate of 4 to 20% in the general population) the accuracy was estimated to be 86.5% (95% CI: 82.0% to 90.6%). This is a good result.
- The estimated prevalence of dyslexia in the population taking up the QuickScreen dyslexia screener will be higher than in the general population, as these are people electing to take the test and are potentially experiencing difficulties. When using a prevalence of 78.8% (estimated from our previous research) the QuickScreen test was estimated to have a higher overall accuracy rate of 92.4% (95% CI: 89.7% to 94.9%). This higher result is more likely to be a truer reflection of the accuracy of the QuickScreen test.
- The sensitivity for the test, the percentage of participants with dyslexia receiving a positive test result, was 94.2% (95% CI: 89.8% to 96.8%). The sensitivity does not depend on the prevalence of dyslexia and this means that the QuickScreen test correctly identifies 94.2% of participants taking the test who have dyslexia, which is a good result for those involved in the screening process.

Results in More Detail

Based on the data for the dyslexic and non-dyslexic groups and to maximise the overall accuracy of the test, participants with a quotient greater than 3.75 (or equivalently a dyslexia percentile > 0.36) should be considered test positive (indicated to have dyslexia) and those with a quotient ≤ 3.75 considered test negative (indicated to not have dyslexia). This cut-off aims to identify the quotient figure between the possible existence of dyslexia and a lack of

symptoms, as a dyslexia screener. This was also the cut-off that maximised the sensitivity and specificity of the test. Based on this threshold, and assuming an estimated prevalence of dyslexia in the population of 10% (a reasonable mid-point between the estimate of 4 to 20% and i.e., reflecting the results that we might expect if the test were applied to a random sample of the general population), the QuickScreen test was estimated to have a high overall accuracy rate of 86.5% (95% confidence interval [CI]: 82.0 to 90.6%, reflecting sampling variability).

As the QuickScreen test is a dyslexia screener and participants self-identify for a test, it is likely that the prevalence of dyslexia among participants is higher than that in the general population. Our previous research indicated that a figure of 78.8% might be a more appropriate estimate for the prevalence among QuickScreen test takers. Using this estimate of prevalence, the QuickScreen test was estimated to have a higher overall accuracy rate of 92.4% (95% confidence interval [CI]: 89.7% to 94.9%).

The sample sensitivity, the percentage of participants with dyslexia receiving a positive test result, was 94.2% (95% CI: 89.8% to 96.8%). The sample specificity, the percentage of participants without dyslexia receiving a negative test result, was lower (but remained high) at 85.7% (95% CI: 79.9% to 90.0%). Maximising sensitivity is likely to be preferable for a diagnostic test to reduce the possibility of false negatives (i.e., participants with dyslexia receiving a negative test result) compared to maximising specificity which reduces the possibility of false positives (i.e., participants without dyslexia receiving a positive result). The specificity result may be impacted by the makeup of the non-dyslexic group in this study who have not been formally assessed for dyslexia. It is possible that there are members of this group who have undiagnosed dyslexia and that if a true control group were available, the specificity result would be higher (also impacting the overall accuracy figures).

The Receiver Operating Characteristic (ROC) area under the curve (AUC) was estimated to be 94.9% (95% CI: 92.7 to 97.1%). Given that the AUC represents the discrimination of the test where 100% is the best possible value (perfect classification), this illustrates that the QuickScreen test has strong predictive capacity for dyslexia.

We also analysed the link between speed of processing and dyslexia (a finding of a previous study), to further explore the extent to which slow processing might be an aggravating symptom for dyslexia and recognising the relevance of fast/efficient processing skills in high achievers. There was a statistically significant association between the QuickScreen general speed of processing result (Difficulties/Average/No Difficulties) and the non-dyslexic/dyslexic group; along with evidence of a better average speed of processing score for the non-dyslexics versus dyslexic participants. Therefore, speed of processing may be useful in identifying potential difficulties in learning profiles, as a standalone characteristic. Additionally, we found a statistically significant association between the speed of processing results and severity of dyslexia, measured as the dyslexia quotient minus the processing speed disparity factor, i.e., removing the speed of processing contribution from the quotient. For both dyslexics and non-dyslexics, participants with a worse speed of processing score tended to have a higher adjusted dyslexia quotient. A higher adjusted quotient was also observed on average for those with difficulties, followed by the average group, and then no difficulties with speed of processing. So, for participants in the dyslexic group, those with worse speed of processing results are associated with more severe dyslexia. Similarly, albeit at a lower level, for participants in the non-dyslexic group, those with worse speed of processing results are associated with more evidence of dyslexic symptoms (and equally those with better speed of processing results are associated with less of evidence of dyslexic symptoms).

Discussion/Context

The QuickScreen test results are almost entirely based on the candidates' current performance and a positive conclusion of Mild, Moderate or Strong indicators will have been adjusted in the light of attainment levels in verbal processing, literacy, and speed of processing. Whilst these can be seen as contributory elements, they are not necessarily the determining factors of dyslexia, and most likely not so when occurring in isolation in an otherwise consistent set of high-performance results. Therefore, it is possible to have a low result on one or more of these components but not be dyslexic.

Likewise, degrees of compensation are also taken into consideration by the QuickScreen test and may positively influence a dyslexia indication by reducing it to a 'Mild', 'Borderline' or even 'None' category where these other attainment levels are found to be satisfactory. To that extent the test result is not a diagnosis, but it is designed to act

as a 'functional dyslexia screener' that provides immediate and detailed insights into an individual's current learning profile and upon which individual support programmes can be devised, reasonable adjustments put in place at work and where possible additional time in written examinations be considered.

Contents

Introduction

Select were pleased to be asked to help again with the statistical analysis of Pico Educational Systems Ltd's QuickScreen dyslexia test[1], on behalf of Dr Dee Walker. QuickScreen is an adult computerised screening test, developed with the aim of providing a reasonably in-depth assessment of dyslexia. The test delivers an indication of possible dyslexia without the need for users to undergo a costly professional assessment by an educational or occupational psychologist.

In this study, we provide an assessment of the diagnostic accuracy of the latest version of QuickScreen based on data from tests completed between February and July 2024. An essential step in the evaluation process of any diagnostic/screening test is to assess its accuracy via diagnostic accuracy measures. Rather than considering QuickScreen's categorical boundaries, we analysed the test's dyslexia quotient (degree of consistency with a dyslexia profile, scored on a scale from 0 to 20), which is calculated by combining individual scores for various processes examined during the online assessments, such as visual, verbal, memory, reading, comprehension, etc. The cut-off values of the quotient score that best discriminate between those with and without a previous dyslexia diagnosis were first identified and then used in the subsequent accuracy assessments.

Further data from the QuickScreen test assessment were available for participants without a previous dyslexia diagnosis , but who self-identified as having life-long difficulties with literacy or who have a family history of dyslexia and so were therefore considered as being "at risk" of having (undiagnosed) dyslexia. We were also asked to conduct a repeat of the diagnostic accuracy assessments considering this group as dyslexia positive (though there was no way in which their presence or absence of dyslexia could be verified).

Finally, we were also asked to explore the speed of processing component results available from the QuickScreen test and how these are associated with the presence or absence of a previous dyslexia diagnosis. The interest being in the potential connection between slow processing and dyslexia and whether speed of processing, as a standalone characteristic, may be useful in identifying potential difficulties in learning profiles. Additionally, we were asked to explore the association between the speed of processing component results with the QuickScreen dyslexia quotient. AS the processing speed disparity factor is a component of the QuickScreen dyslexia quotient we subtracted the speed of processing contribution from the quotient, to understand how the severity of dyslexia might correlate with slow processing.

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 completing the online QuickScreen assessment from 1st February 2024 to 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 16 to 74) who accessed Pico's services within this time 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:

[1] https://qsdyslexiatest.com/

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

While the following analysis is based on these groups, there are some important points to note, which are discussed in the Potential Limitations section below.

The QuickScreen dyslexia test results were provided in five Excel spreadsheets, one each for the months from February to July. These Excel files all had a consistent layout and were combined prior to analysis to create a single dataset.

The subsequent analysis of the study data was run for two different sets of these available data:

i. The non-dyslexic group vs the dyslexic group.
ii. The non-dyslexic group vs the dyslexic group and the "at risk" group (i.e., considering the "at risk" participants in the dyslexic group).

For the primary analysis (i), test results were available for 369 participants: 185 (50.1%) in the dyslexic group; and 184 (49.9%) in the non-dyslexic group. There were 719 "at risk" participants who were also considered in the dyslexic group in the additional exploratory analysis (ii).

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.

Potential Limitations

We recognise that there are some potential limitations of the study, given the data available for analysis, that may affect its outcomes. In most cases, these are likely to lead to conservative estimates of the test accuracy, i.e., the reported results may underestimate the true performance of the test in practice.

Firstly, we note that 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 (see Brèthes et al (2022), Fink (1998)[2]). Pico Educational Systems have highlighted that the

[2] Brèthes, H., Cavalli, E., Denis-Noël, A. , Melmi, J., El Ahmadi, A., Bianco, M., Colé, P. (2022) 'Text Reading Fluency and Text Reading Comprehension Do Not Rely on the Same Abilities in University Students With and Without Dyslexia', *Frontiers in Psychology, 13,* doi: 10.3389/fpsyg.2022.866543
Fink, R.P. Literacy development in successful men and women with dyslexia. *Ann. of Dyslexia* **48**, 311–346 (1998). https://doi.org/10.1007/s11881-998-0014-5

QuickScreen test is only able to identify those with 'functional' dyslexia, i.e., those that are currently exhibiting problems. Any well-compensated individuals may be asymptomatic or more borderline in their dyslexia symptoms and this would therefore impact upon the accuracy assessments reported in this study as the test may find it more difficult to identify these lesser symptoms linked with dyslexia. When presenting the results of the test to participants, QuickScreen provides a caveat/explanation that in the absence of other key indicators (e.g., deficiencies in literacy levels) a dyslexia diagnosis is unlikely. Furthermore, the graduated indications provided by QuickScreen in their presentation of the test results reflect this non-binary nature of dyslexia which is on a continuum of symptoms/severities, whereas the diagnostic accuracy summaries presented here are not able to account for these graduated indications and this uncertainty.

Secondly, we also acknowledge that those in the non-dyslexic group may have unidentified learning problems which means that they may have indictors of dyslexia but be unaware of these issues. The presence of such participants will again have the potential to reduce the apparent accuracy of the QuickScreen test, as reported in this study. 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 QuickScreen may report a positive albeit weak indication of dyslexia (not "None", for example) for a participant in the non-dyslexic group, it is understood that this subject could in fact have undiagnosed dyslexia. The effect of this potential misclassification of participants is known as classification bias. The implication of which is that it may not be possible to achieve perfect diagnostic accuracy in this case.

Similar to our previous studies, it should also be noted when interpreting the results of this analysis that their validity depends on the sample of participants and how representative they are to the population of interest. This includes, not only the proportion of people in the population with dyslexia, but also the spectrum of severity of dyslexia in the sample. Where this might not reflect the target population, a study is sometimes said to suffer from "spectrum bias".

Methods

Receiver Operating Characteristic (ROC) Curve Analysis

A Receiving Operating Characteristic (ROC) curve[3,4] is a useful tool that allows us to examine the trade-off between the QuickScreen test's sensitivity (i.e., the proportion of dyslexic participants that are identified as having dyslexia by the test) and specificity (i.e., the proportion of non-dyslexics that are identified as not having dyslexia by the test). 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. Each point on the ROC curve represents a different threshold for classification, ranging from all quotients classified as non-dyslexic in the bottom left-hand corner (i.e., 0% TPR and FPR) and all quotients classified as 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 considered two potential options for the choice of optimal threshold to give the best discrimination between the dyslexic/non-dyslexic groups:

i. To maximise the TPR + (1–FPR), i.e., the maximum sensitivity + specificity.
ii. To maximise the overall accuracy, i.e., the proportion of results that are correctly identified by the test.

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)[5]. 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 (using the DeLong[6] method).

Diagnostic Accuracy Assessments

As described above, the sensitivity (or TPR) of a diagnostic test indicates how good it is at finding people with the condition in question. It is the probability that someone who has the condition is identified as such by the test. Whereas the specificity (1–FPR) of a diagnostic test indicates how good

[3] https://select-statistics.co.uk/resources/glossary-page/#receiver-operating-characteristic-roc-curve
[4] https://select-statistics.co.uk/blog/classifying-binary-outcomes/
[5] https://select-statistics.co.uk/resources/glossary-page/#roc-area-curve-auc
[6] Elisabeth R. DeLong, David M. DeLong and Daniel L. Clarke-Pearson (1988) "Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach". Biometrics 44, 837–845.

it is at identifying people who do not have the condition. It is the probability that someone who does not have the condition is identified as such by the test.

The predictive values of the test, also termed the “post-test probabilities”, provide the probability of a positive or negative diagnosis given the test result. The predictive values therefore provide important information on the diagnostic accuracy of the test for a particular participant, answering the question “How likely is it that I have or don’t have dyslexia given the test result that I have received?”

To assess the performance of the current QuickScreen test based on the dyslexia quotient cut-offs identified in the ROC curve analysis, as described above, we produced a number of diagnostic accuracy assessment summaries, including estimates of the sensitivities, specificities, and predictive values.

The sensitivity and specificity of a test can be calculated from the sample data. The predictive values depend on the prevalence of the conditions in question in the population, i.e., the proportions of individuals who have dyslexia, as well as the sensitivity and specificity of the test. As the sample of data available are a selection of “cases” with a positive dyslexia diagnosis and “controls” with a negative dyslexia diagnosis from observational data, rather than a random sample from the population, the true prevalence is unknown. Therefore, we can’t reliably estimate the predictive values directly from the data available. Here we assumed an estimated prevalence of dyslexia in the population of 10% when calculating the predictive values. In screening situations, the prevalence is almost always small and the positive predictive value low, even for a fairly sensitive and specific test. This reflects the results for the predictive values that we might expect if the test were applied to a random sample of the general population, for whom the prevalence is approximately 10%. However, the prevalence in those that have self-selected to take the QuickScreen dyslexia test is likely to be considerably higher. Therefore, the predictive value results were also calculated for a higher estimate of the prevalence in line with this alternative self-selecting population, using the rate of dyslexia observed in our original study of QuickScreen (ref: PICO001), i.e., 78.8%, which included participants where an independent assessment of their dyslexia diagnosis was available. (In this study, the observed prevalence will be arbitrarily affected by the number of control group participants that have been included and therefore cannot be used as a reliable estimate of the prevalence in this alternative population.)

In addition to the diagnostic accuracy measures described above, estimates of the overall accuracy of the test were also calculated, i.e., the overall proportion of correctly classified participants, which was the key outcome of interest in this study. To express our uncertainty in the overall accuracy, 95% bootstrapped confidence intervals were also calculated. We note that, similar to the predictive values, the overall accuracy also depends upon the assumed prevalence of dyslexia and is therefore provided for the two populations with corresponding prevalence estimates considered (10% and 78.8%).

Alongside the diagnostic accuracy measures, we have carried out a statistical test to assess whether there is evidence of an association between the QuickScreen test outcome and the independent dyslexia diagnosis. This would be expected if the test is useful in discriminating between dyslexic and non-dyslexic individuals. Fisher’s exact test was applied as this can be used with both large and small samples and because the computational intensity required is not a problem with modern computing power.

At Risk Group Exploration

A further exploratory analysis was also carried out, considering the “at risk” group as dyslexics.

General Speed of Processing Exploration

Another area of interest, for Dr Dee Walker, was to explore the QuickScreen speed of processing results and their association with dyslexia.

Therefore, in this study, we looked at the association between the speed of processing (which is categorised into No Difficulties/Average/Difficulties) and the dyslexic/non-dyslexic groups and carried out a statistical test (a Fisher’s exact test) of their independence. We also explored the relationship between the numeric speed of processing scores and the previous dyslexia diagnosis groups, using summary statistics and visualisations, and a statistical (Mann-Whitney U) test to compare their distributions.

Furthermore, we considered whether the extent of other dyslexic symptoms might be associated with the QuickScreen speed of processing results. As the QuickScreen quotient incorporates a speed of processing disparity component and therefore will intrinsically be correlated with the speed of processing results, we looked at speed of processing versus the dyslexia quotient minus the processing speed disparity component. We calculated the correlation between these values and compared the average adjusted dyslexia quotient across the general speed of processing groups (No Difficulties, Average, Difficulties) (via a Kruskal-Wallis rank sum test).

Results

The results of the analysis outlined in the Methods section are presented below, first for the primary analysis considering the non-dyslexic group and the dyslexic group, then an additional exploratory analysis including the "at risk" group.

Dyslexic and Non-Dyslexic Group

The ROC curve for the dyslexic and non-dyslexic group analysis is shown in Figure 1. The ROC curve AUC is estimated to be 94.91%, with 95% confidence interval from 92.70% to 97.12%. Given that the AUC of a perfect model would be 100%, this illustrates that the QuickScreen test has strong predictive capacity for dyslexia and is maintaining its effectiveness when screening for dyslexia.

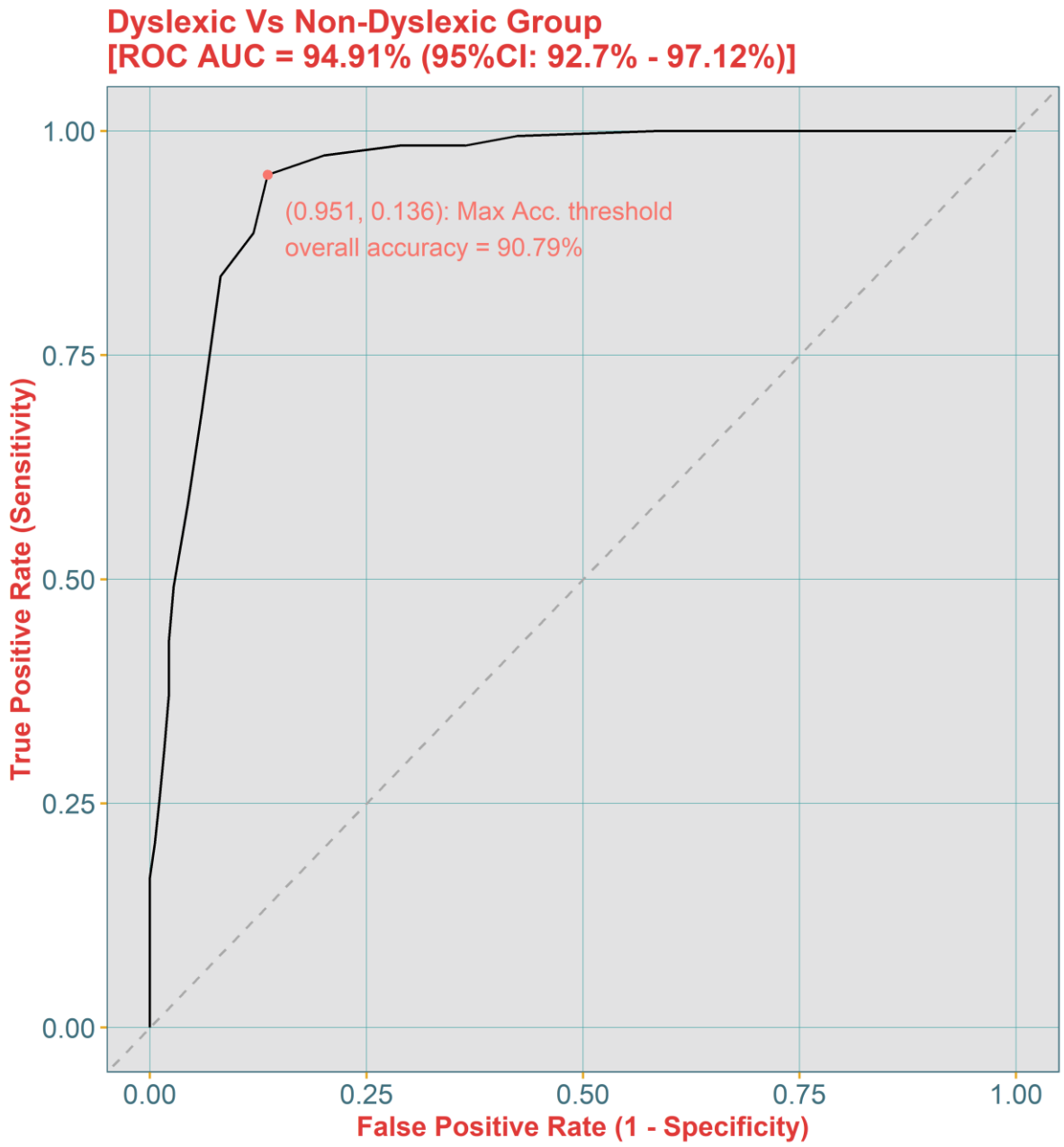

Figure 1: ROC Curve for the non-dyslexic versus dyslexic group, with point (TPR, FPR) showing the threshold associated with maximising the overall accuracy, which also corresponds with maximising the sensitivity + specificity.

Overall Accuracy and Sensitivity + Specificity Threshold

The dyslexia quotient cut-off associated with maximising the overall accuracy (the red point on Figure 1) was the same dyslexia quotient cut-off associated with maximising the sensitivity and specificity. The threshold was 3.75 (or equivalently a dyslexia percentile > 0.36). Therefore, to maximise the overall accuracy and also maximise the sensitivity and specificity of the test, participants with a quotient greater than 3.75 should be considered test positive (indicated to have dyslexia) and those ≤ 3.75 test negative (indicated to not have dyslexia).

The distribution of the QuickScreen dyslexia quotient values observed in the non-dyslexic (previous diagnosis negative) and dyslexic (previous diagnosis positive) groups, along with this optimal threshold are visualised in Figure 2.

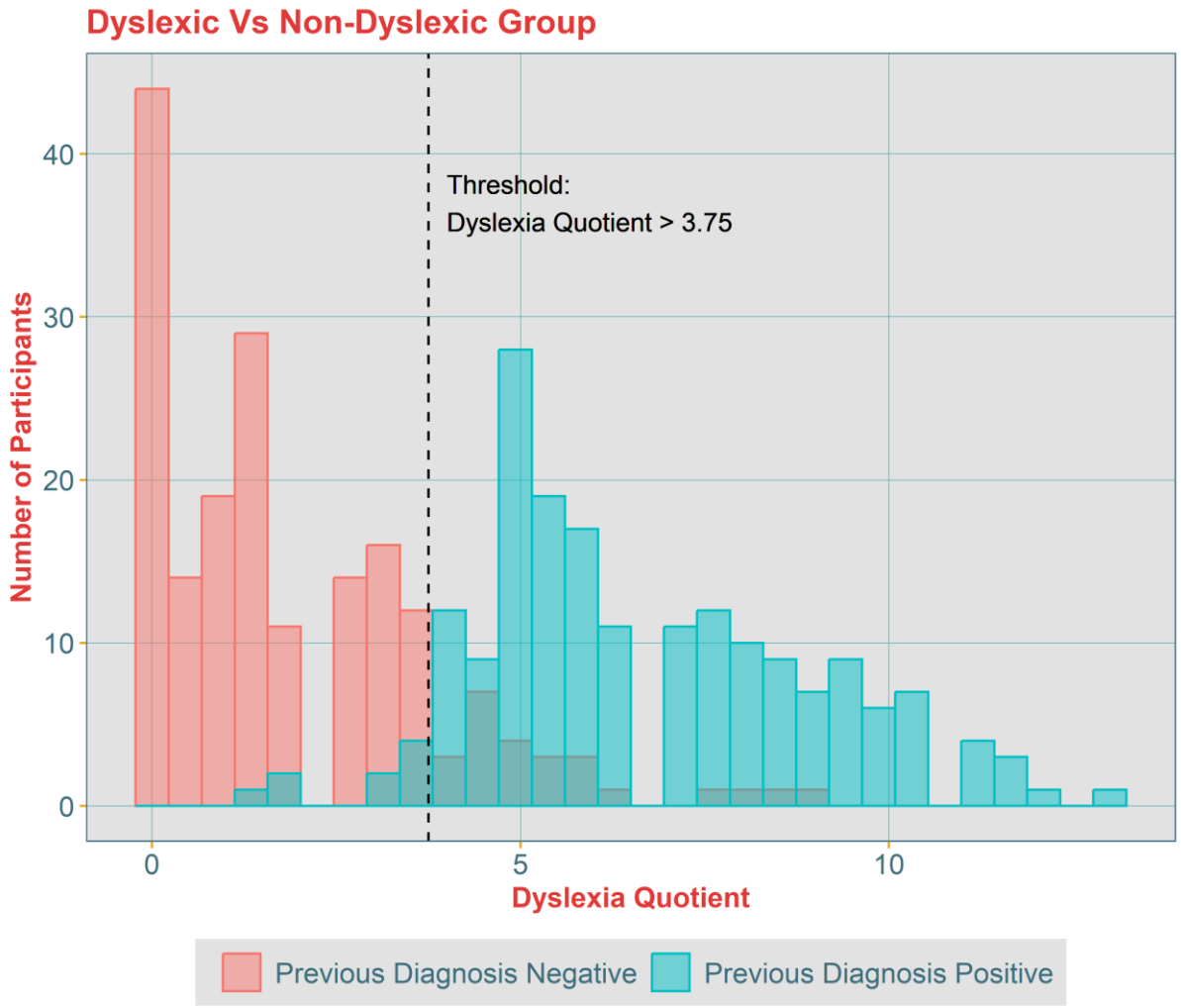

Figure 2: Histograms of the QuickScreen dyslexia quotients for the participants in the non-dyslexic (previous diagnosis negative) and dyslexic (previous diagnosis positive) groups. The vertical, dashed line shows the dyslexia quotient threshold associated with maximising the overall accuracy and sensitivity and specificity.

Applying this threshold, 168 (45.5%) of participants were test negative and 201 (54.5%) test positive, compared with 184 (49.9%) in the non-dyslexic group and 185 (50.1%) in the dyslexic group (as shown in the crosstabulation in Table 1). A Fisher's exact test (on the data in Table 1) finds strong statistical

evidence (p-value < 0.0001) of an association between the dyslexia group and the QuickScreen test result.

	QuickScreen Test Negative	QuickScreen Test Positive	Total
Non-Dyslexic Group	159	25	184 (49.9%)
Dyslexic Group	9	176	185 (50.1%)
Total	168 (45.5%)	201 (54.5%)	369 (100%)

Table 1: Crosstabulation of the dyslexia group (non-dyslexics/dyslexics) versus the QuickScreen test result (negative/positive) based on the threshold associated with maximising the overall accuracy and the sensitivity and specificity.

The proportion of participants in the non-dyslexic group who received a negative QuickScreen test result (i.e., sample specificity) and the proportion of participants in the dyslexic group who received a positive QuickScreen test result (i.e., sample sensitivity), based on this threshold, are shown in Table 2.

	QuickScreen Test Negative	QuickScreen Test Positive
Non-Dyslexic Group	86.4%	13.6%
Dyslexic Group	4.9%	95.1%

Table 2: Raw sample specificity (non-dyslexic group row) and sensitivity (dyslexic group row) values for the QuickScreen test negative and positive results, based on the threshold associated with maximising the overall accuracy and the sensitivity and specificity.

Eighty-six-point-four percent (86.4%) of participants in the non-dyslexic group received a negative test result, and 95.1% of those in the dyslexic group received a positive test result.

Of those participants who received negative QuickScreen test outcome, the proportion who were in the non-dyslexic group (i.e., sample negative predictive value); and of those participants who received a positive QuickScreen test outcome, the proportion who were in the dyslexic group (i.e., sample positive predictive value), are shown in Table 3.

Ninety-four-point-six percent (94.6%) of those participants with a negative QuickScreen test result were in the non-dyslexic group, and 87.6% with a positive QuickScreen test result were in the dyslexic group.

	QuickScreen Test Negative	QuickScreen Test Positive
Non-Dyslexic Group	94.6%	12.4%
Dyslexic Group	5.4%	87.6%

Table 3: Raw sample predictive values (negative for the non-dyslexic group and positive for the dyslexic group) for the QuickScreen test negative and test positive outcomes, based on the threshold associated with maximising the overall accuracy and the sensitivity and specificity.

Overall, 90.8% ([159+176]/369) of the QuickScreen test results were correct according to the non-dyslexic/dyslexic groups. These are the raw sample predictive values and overall accuracy, based on the observed sample prevalence, and do not reflect estimates for a random sample of the population nor those self-selecting for a QuickScreen test.

The diagnostic accuracy measures, estimated using the adjusted method, to provide a better estimate (with adjusted logit confidence intervals[7]) and assuming a 10% prevalence of dyslexia, are shown in Table 4.

QuickScreen Test Result	Diagnostic Measure	Estimate	95% Confidence Interval
Positive	Sensitivity	94.2%	(89.8%, 96.8%)
	PPV	42.2%	(34.0%, 50.9%)
Negative	Specificity	85.7%	(79.9%, 90.0%)
	NPV	99.3%	(98.7%, 99.6%)
Overall	Accuracy	86.5%	(82.0%, 90.6%)

Table 4: Estimates of the diagnostic accuracy measures using the adjusted logit method, based on the threshold associated with maximising the overall accuracy and the sensitivity and specificity (with 10% prevalence). PPV = Positive Predictive Value; NPV = Negative Predictive Value.

So, assuming an estimated prevalence of dyslexia in the population of 10%:

- The overall accuracy of the QuickScreen test (proportion of test results that are correct) is estimated to be 86.5%, with a 95% confidence interval [CI] expressing our uncertainty in this estimate of (82.0% to 90.6%).
- The sensitivity (proportion of those with dyslexia that test positive) of the Quickscreen test is estimated to be 94.2% (95% CI: 89.8% to 96.8%).
- The specificity (proportion of those without dyslexia that test negative) is estimated to be 85.7% (95% CI: 79.9% to 90.0%).
- The positive predictive value (proportion of those with a positive test that have dyslexia) is estimated to be 42.2% (95% CI: 34.0% to 50.9%).
- The negative predictive value (proportion of those with a negative test that don't have dyslexia) is estimated to be 99.3% (95% CI: 98.7% to 99.6%).

We note that, in screening situations, the prevalence is almost always small and the positive predictive value low, even for a fairly sensitive and specific test. This is reflected in the estimated positive predictive value of 42.2% here, which is impacted by the assumed prevalence of dyslexia in the population. We'll see in the subsequent results below, that for a higher assumed prevalence of dyslexia, the positive predictive value is higher.

While an estimated prevalence of 10% might be appropriate for the general population, it is unlikely to be a good estimate of the prevalence of dyslexia among those taking the QS Dyslexia test. The prevalence calculated in our previous research project (ref: PICO001) was 78.8%. This may be a more accurate estimate that is more indicative of how the test is used.

The diagnostic accuracy measures, again estimated using the adjusted method (with adjusted logit confidence intervals) but assuming a 78.8% prevalence of dyslexia, are shown in Table 5.

[7] Using the logit transformation in calculating the confidence interval can also help to meet the assumptions of normality and avoid producing limits beyond the possible boundary values of 0 and 100%. For further information and the formulae applied see Mercaldo, Nathaniel David; Zhou, Xiao-Hua; and Lau, Kit F., "Confidence Intervals for Predictive Values Using Data from a Case Control Study" (December 2005). UW Biostatistics Working Paper Series. Working Paper 271. http://biostats.bepress.com/uwbiostat/paper271

QuickScreen Test Result	Diagnostic Measure	Estimate	95% Confidence Interval
Positive	Sensitivity	94.2%	(89.8%, 96.8%)
	PPV	96.1%	(94.5%, 97.2%)
Negative	Specificity	85.7%	(79.9%, 90.0%)
	NPV	79.9%	(69.1%, 87.7%)
Overall	Accuracy	92.4%	(89.7%, 94.9%)

Table 5: Estimates of the diagnostic accuracy measures using the adjusted logit method, based on the threshold associated with maximising the overall accuracy and the sensitivity and specificity (with 78.8% prevalence). PPV = Positive Predictive Value; NPV = Negative Predictive Value.

The estimates of the sensitivity and specificity are unaffected by the change in assumed prevalence of dyslexia. However, based on this higher estimate of the prevalence of dyslexia for participants who have self-identified to take the test:

- The overall accuracy of the QuickScreen test (proportion of test results that are correct) is estimated to be 92.4% (95% CI: 89.7% to 94.9%).
- The positive predictive value (proportion of those with a positive test that have dyslexia) is estimated to be 96.1% (95% CI: 94.5% to 97.2%).
- The negative predictive value (proportion of those with a negative test that don't have dyslexia) is estimated to be 79.9% (95% CI: 69.1% to 87.7%).

When calculating the overall accuracy at a given level of prevalence, the sensitivity and specificity are weighted by the prevalence and (1 – prevalence) respectively. When the prevalence is estimated at 10% the weights are 0.1 and 0.9 respectively, and specificity contributes more than the sensitivity. When the overall accuracy is calculated for a prevalence estimated at 78.8% the weights are 0.788 and 0.212 respectively, so sensitivity contributes more than the specificity. Hence why the accuracy is higher in this instance.

We note that for this higher assumed prevalence the positive predictive value is estimated to be much higher at over 96%. However, the negative predictive value has correspondingly decreased to almost 80%.

At Risk Group

The results of the exploratory analysis detailed in the Methods section for the "at risk" group are presented below. In this analysis, we repeated the steps carried out to analyse the diagnostic accuracy measures for the non-dyslexic versus dyslexic group analysis presented above, but including the "at risk" group as dyslexics.

As shown in the histograms in Figure 3, the "at risk" group have dyslexia quotients that span the same range as the dyslexic and non-dyslexic groups, although there are fewer "at risk" participants with dyslexia quotients at the lower end of the score range: there are more non-dyslexic (previous diagnosis negative) participants at the lower end of the score range. This is perhaps not surprising as these "at risk" participants do not have a previous positive dyslexia diagnosis, but either have self-identified as having difficulties with their learning or have a family history of dyslexia.

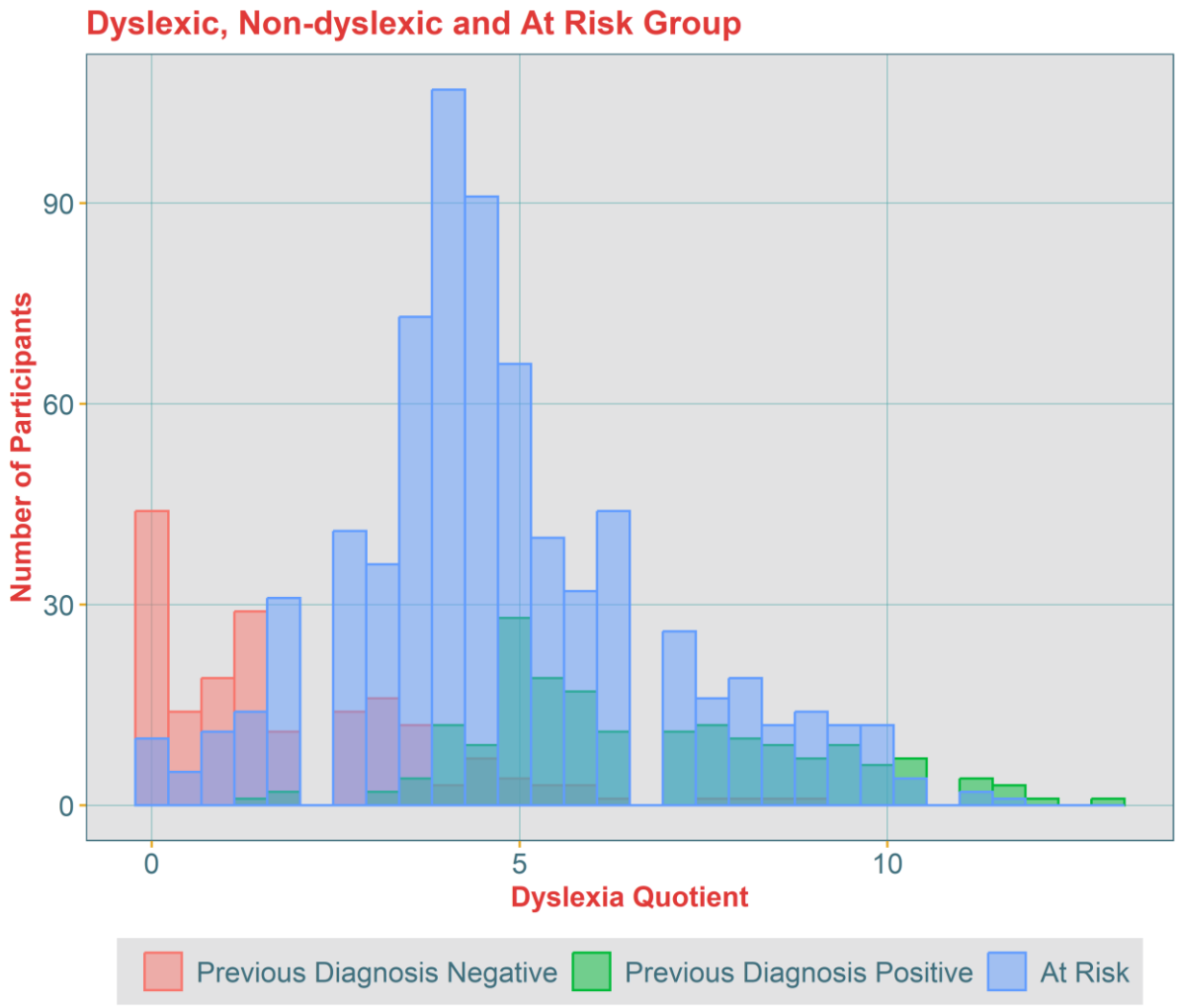

Figure 3: Histograms of the QuickScreen dyslexia quotients for the participants in the non-dyslexic (previous diagnosis negative), dyslexic (previous diagnosis positive) and "at risk" groups.

Ultimately, these additional data boost the sample size available for analysis, and we consider the diagnostic accuracy measures when these additional "at risk" data are included.

The ROC curve for the dyslexic and non-dyslexic group analysis including the "at risk" group is shown in Figure 4. The ROC curve AUC is estimated to be 87.22%, with 95% confidence interval from 84.16%

to 90.28%. Given that the AUC of a perfect model would be 100%, this illustrates that the QuickScreen test has strong predictive capacity for dyslexia and may be useful when screening for dyslexia.

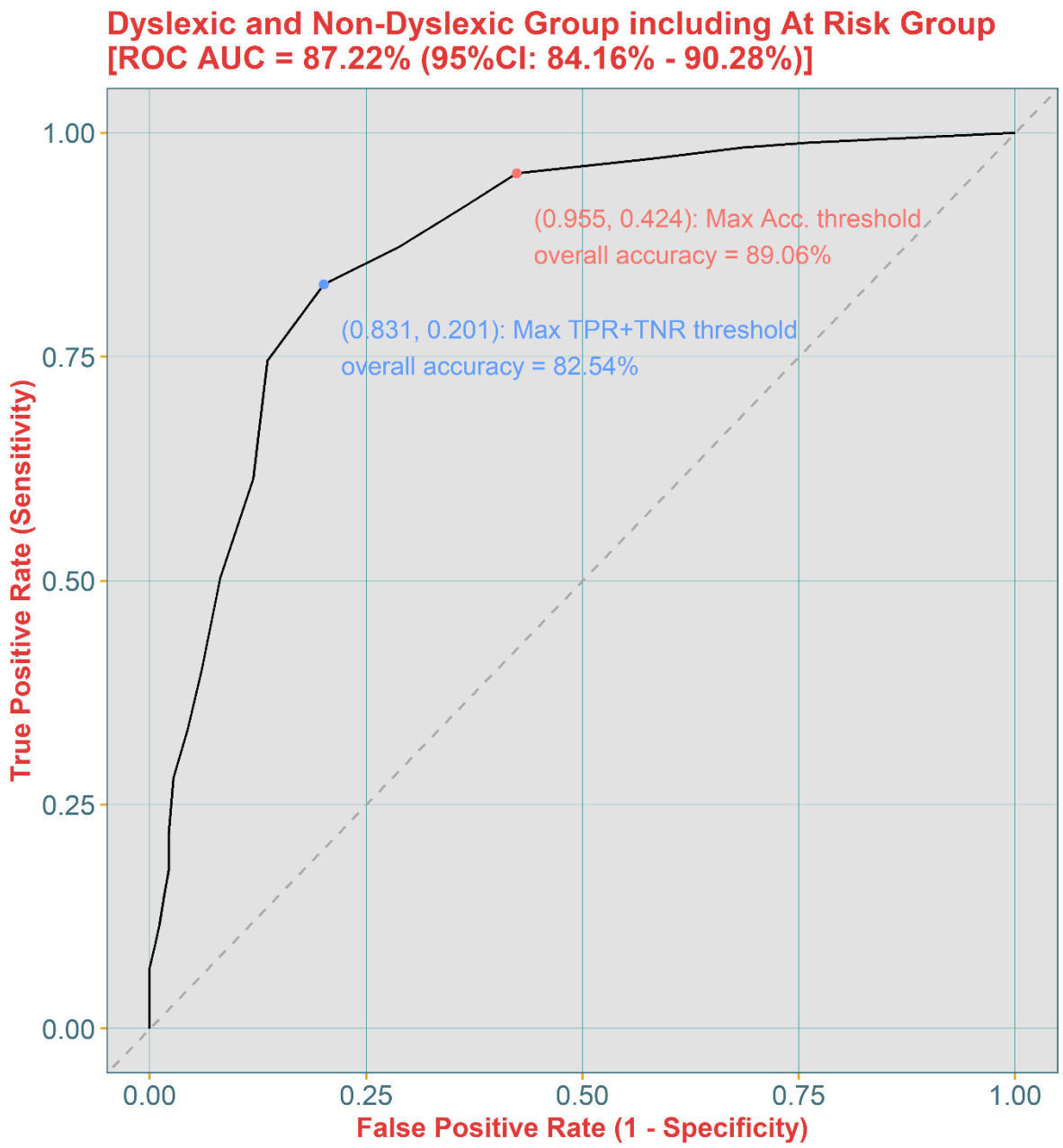

Figure 4: ROC Curve for the non-dyslexic versus dyslexic group including the "at risk" participants, with points (TPR, FPR) showing the thresholds associated with maximising the sensitivity + specificity (in blue) and maximising the overall accuracy (in red).

Overall Accuracy Threshold

The dyslexia quotient cut-off associated with maximising the overall accuracy (red point on Figure 4) was 1.75 (or equivalently a dyslexia percentile > 0.24). Therefore, to maximise the overall accuracy of the test, participants with a quotient greater than 1.75 should be considered test positive (indicated to have dyslexia) and those ≤ 1.75 test negative (indicated to not have dyslexia).

The distribution of the QuickScreen dyslexia quotient values observed in the non-dyslexic (previous diagnosis negative) and dyslexic (previous diagnosis positive and "at risk") groups, along with this optimal threshold are visualised in Figure 5.

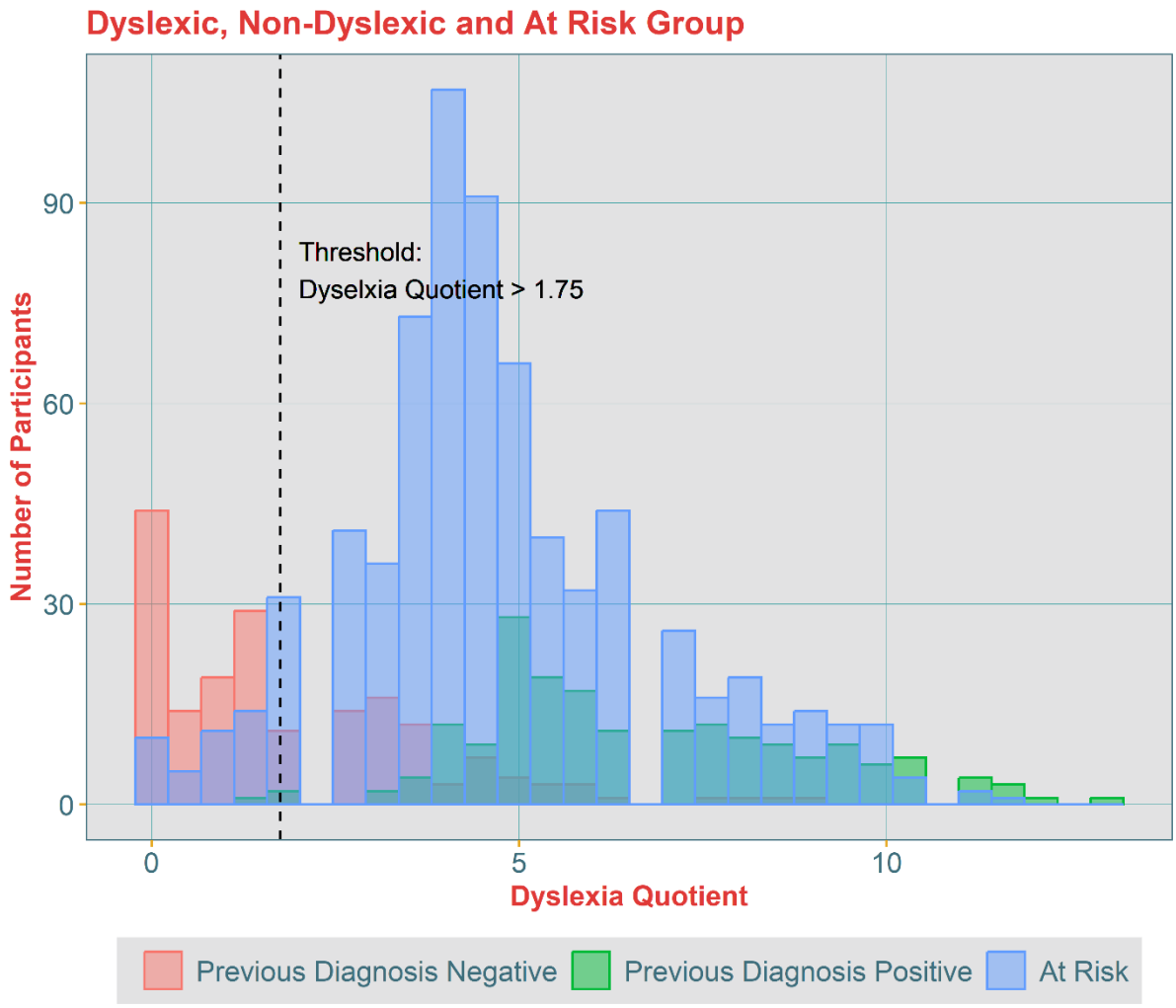

Figure 5: Histograms of the QuickScreen dyslexia quotients for the participants in the non-dyslexic (previous diagnosis negative) and dyslexic (previous diagnosis positive and "at risk") groups. The vertical, dashed line shows the dyslexia quotient threshold associated with maximising the overall accuracy.

Applying this threshold, 147 (13.5%) participants were test negative and 941 (86.5%) test positive, compared with 184 (16.9%) in the non-dyslexic group and 904 (83.1%) in the dyslexic group, including "at risk" participants (as shown in the crosstabulation in Table 6). A Fisher's exact test (on the data in Table 6) finds strong statistical evidence (p-value < 0.0001) of an association between the dyslexia group and the QuickScreen test result.

	QuickScreen Test Negative	QuickScreen Test Positive	Total
Non-Dyslexic Group	106	78	184 (16.9%)
Dyslexic Group	41	863	904 (83.1%)
Total	147 (13.5%)	941 (86.5%)	1088 (100%)

Table 6: Crosstabulation of the dyslexia group (non-dyslexics/dyslexics) versus the QuickScreen test result (negative/positive) based on the threshold associated with maximising the overall accuracy, for the non-dyslexic group and the dyslexic group including "at risk" participants.

The proportion of participants in the non-dyslexic group who received a negative QuickScreen test result (i.e., sample specificity) and the proportion of participants in the dyslexic group who received a positive QuickScreen test result (i.e., sample sensitivity), based on this threshold, are shown in Table 7.

	QuickScreen Test Negative	QuickScreen Test Positive
Non-Dyslexic Group	57.6%	42.4%
Dyslexic Group	4.5%	95.5%

Table 7: Raw sample specificity (non-dyslexic group row) and sensitivity (dyslexic group row) values for the QuickScreen test negative and positive results, based on the threshold associated with maximising the overall accuracy, for the non-dyslexic group and the dyslexic group including "at risk" participants.

Fifty-seven-point-six percent (57.6%) of participants in the non-dyslexic group received a negative test result, and 95.5% of those in the dyslexic group received a positive test result.

Of those participants who received negative QuickScreen test outcome, the proportion who were in the non-dyslexic group (i.e., sample negative predictive value); and of those participants who received a positive QuickScreen test outcome, the proportion who were in the dyslexic group (i.e., sample positive predictive value), are shown in Table 8.

	QuickScreen Test Negative	QuickScreen Test Positive
Non-Dyslexic Group	72.1%	8.3%
Dyslexic Group	27.9%	91.7%

Table 8: Raw sample predictive values (negative for the non-dyslexic group and positive for the dyslexic group) for the QuickScreen test negative and test positive outcomes, based on the threshold associated with maximising the overall accuracy, for the non-dyslexic group and dyslexic group including "at risk" participants.

Seventy-two-point-one percent (72.1%) of those participants with a negative QuickScreen test result were in the non-dyslexic group, and 91.7% with a positive QuickScreen test result were in the dyslexic group.

Overall, 89.1% ([106+863]/1088) of the QuickScreen test results were correct according to the non-dyslexic/dyslexic groups. These are the raw sample predictive values and overall accuracy, based on the observed sample prevalence, and do not reflect estimates for a random sample of the population nor those self-selecting for a QuickScreen test.

The diagnostic accuracy measures, estimated using the adjusted method (with adjusted logit confidence intervals) and assuming a 10% prevalence of dyslexia, based on the threshold associated with maximising the overall accuracy, are shown in Table 9.

QuickScreen Test Result	Diagnostic Measure	Estimate	95% Confidence Interval
Positive	Sensitivity	95.3%	(93.7%, 96.5%)
	PPV	19.9%	(17.4%, 22.7%)
Negative	Specificity	57.5%	(50.3%, 64.3%)
	NPV	99.1%	(98.8%, 99.3%)
Overall	Accuracy	61.2%	(54.8%, 67.4%)

Table 9: Estimates of the diagnostic accuracy measures using the adjusted logit method, based on the threshold associated with maximising the overall accuracy, for the non-dyslexic group and the dyslexic group including "at risk" participants (with 10% prevalence). PPV = Positive Predictive Value; NPV = Negative Predictive Value.

So, assuming an estimated prevalence of dyslexia in the population of 10%:

- The overall accuracy of the QuickScreen test (proportion of test results that are correct) is estimated to be 61.2%, with a 95% CI of 54.8% to 67.4%.
- The sensitivity (proportion of those with dyslexia that test positive) of the Quickscreen test is estimated to be 95.3% (95% CI: 93.7% to 96.5%).
- The specificity (proportion of those without dyslexia that test negative) is estimated to be 57.5% (95% CI: 50.32% to 64.3%).
- The positive predictive value (proportion of those with a positive test that have dyslexia) is estimated to be 19.9% (95% CI: 17.4% to 22.7%).
- The negative predictive value (proportion of those with a negative test that don't have dyslexia) is estimated to be 99.1% (95% CI: 98.8% to 99.3%).

We note that, in screening situations, the prevalence is almost always small and the positive predictive value low, even for a fairly sensitive and specific test. This is reflected in the estimated positive predictive value of 19.9% here, which is impacted by the assumed prevalence of dyslexia in the population. We'll see in the subsequent results below, that for a higher assumed prevalence of dyslexia, the positive predictive value is higher.

The diagnostic accuracy measures, again estimated using the adjusted method (with adjusted logit confidence intervals) but assuming a 78.8% prevalence of dyslexia, based on the threshold associated with maximising the overall accuracy, are shown in Table 10.

QuickScreen Test Result	Diagnostic Measure	Estimate	95% Confidence Interval
Positive	Sensitivity	95.3%	(93.7%, 96.5%)
	PPV	89.3%	(87.6%, 90.8%)
Negative	Specificity	57.5%	(50.3%, 64.3%)
	NPV	76.6%	(70.4%, 81.8%)
Overall	Accuracy	87.3%	(85.4%, 89.1%)

Table 10: Estimates of the diagnostic accuracy measures using the adjusted logit method, based on the threshold associated with maximising the overall accuracy, for the non-dyslexic group and the dyslexic group including "at risk" participants (with 78.8% prevalence). PPV = Positive Predictive Value; NPV = Negative Predictive Value.

The estimates of the sensitivity and specificity are unaffected by the change in assumed prevalence of dyslexia. However, based on this higher estimate of dyslexia for participants who have self-identified to take the test:

- The overall accuracy of the QuickScreen test (proportion of test results that are correct) is estimated to be 87.3% (95% CI: 85.4% to 89.1%).
- The positive predictive value (proportion of those with a positive test that have dyslexia) is estimated to be 89.3% (95% CI: 87.6% to 90.8%).
- The negative predictive value (proportion of those with a negative test that don't have dyslexia) is estimated to be 76.6% (95% CI: 70.4% to 81.8%).

We note that for this higher assumed prevalence the positive predictive value is estimated to be much higher at 89%. However, the negative predictive value has correspondingly decreased to 76.6%.

Sensitivity + Specificity Threshold

Alternatively, choosing the threshold that maximises the sensitivity + specificity, rather than the overall accuracy, the dyslexia quotient cut-off (blue point on Figure 4) was 3.25 (or equivalently a dyslexia percentile > 0.32). Therefore, to maximise the sensitivity + specificity of the test, participants with a quotient greater than 3.25 should be considered test positive (indicated to have dyslexia) and those ≤ 3.25 test negative (indicated to not have dyslexia).

The distribution of the QuickScreen dyslexia quotient values observed in the non-dyslexic (previous diagnosis negative), dyslexic (previous diagnosis positive) and "at risk" groups, along with this optimal threshold are visualised in Figure 6.

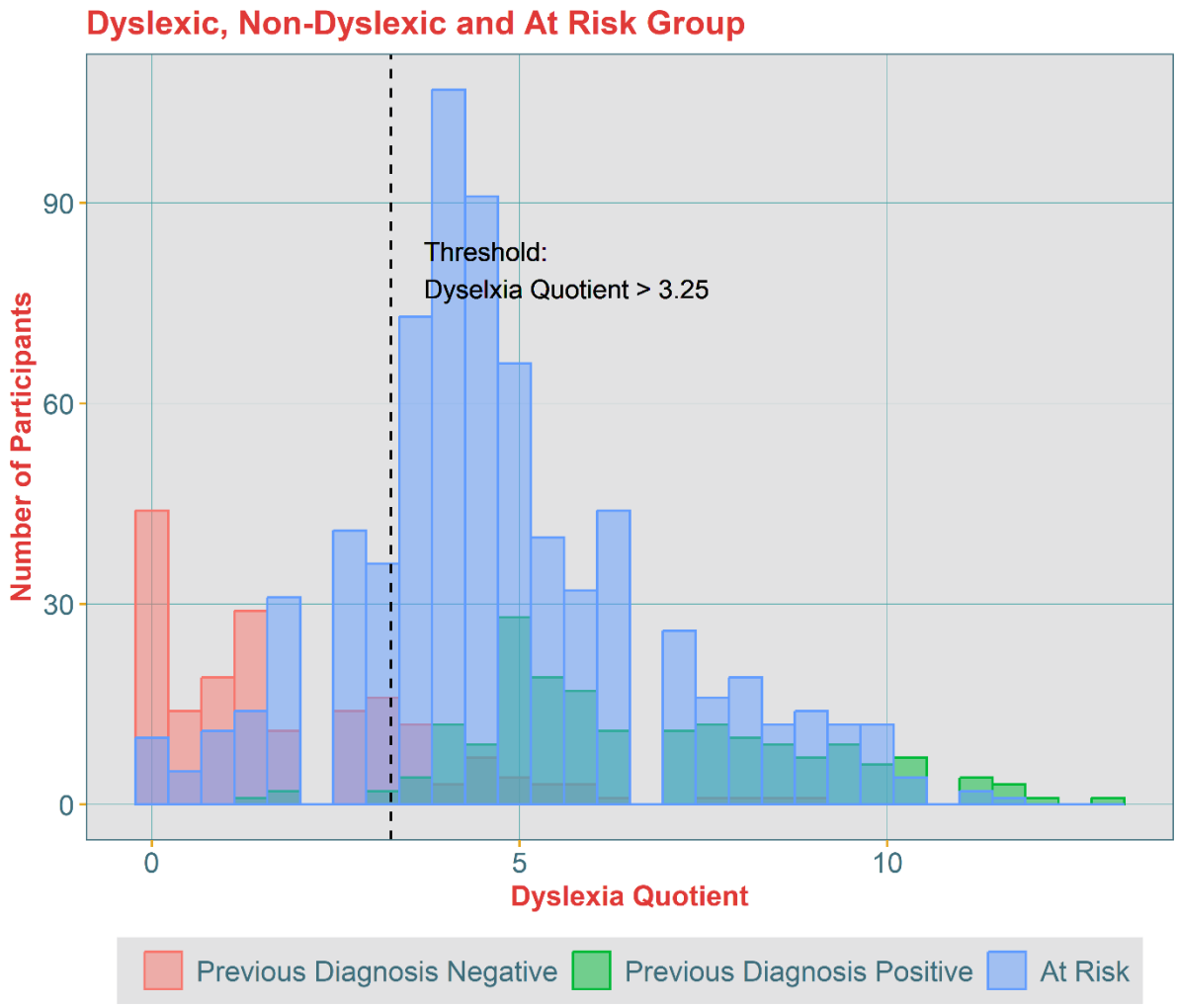

Figure 6: Histograms of the QuickScreen dyslexia quotients for the participants in the non-dyslexic (previous diagnosis negative), dyslexic (previous diagnosis positive) and "at risk" groups. The vertical, dashed line shows the dyslexia quotient threshold associated with maximising the sensitivity + specificity.

Applying this threshold, 300 (27.6%) of participants were test negative and 788 (72.4%) test positive, compared with 184 (16.9%) in the non-dyslexic group and 904 (83.1%) in the dyslexic group, including "at risk" participants (as shown in the crosstabulation in Table 11). A Fisher's exact test (on the data in Table 11) finds strong statistical evidence (p-value < 0.0001) of an association between the dyslexia group and the QuickScreen test result.

	QuickScreen Test Negative	QuickScreen Test Positive	Total
Non-Dyslexic Group	147	37	184 (16.9%)
Dyslexic Group	153	751	904 (83.1%)
Total	300 (27.6%)	788 (72.4%)	1088 (100%)

Table 11: Crosstabulation of the dyslexia group (non-dyslexics/dyslexics) versus the QuickScreen test result (negative/positive) based on the threshold associated with maximising the sensitivity + specificity, for the non-dyslexic group and the dyslexic group including "at risk" participants.

The proportion of participants in the non-dyslexic group who received a negative QuickScreen test result (i.e., sample specificity) and the proportion of participants in the dyslexic group who received a

positive QuickScreen test result (i.e., sample sensitivity), based on this threshold, are shown in Table 12.

	QuickScreen Test Negative	QuickScreen Test Positive
Non-Dyslexic Group	79.9%	20.1%
Dyslexic Group	16.9%	83.1%

Table 12: Raw sample specificity (non-dyslexic group row) and sensitivity (dyslexic group row) values for the QuickScreen test negative and positive results, based on the threshold associated with maximising the sensitivity + specificity, for the non-dyslexic group and the dyslexic group including "at risk" participants.

Seventy-nine-point-nine percent (79.9%) of participants in the non-dyslexic group received a negative test result, and 83.1% of those in the dyslexic group received a positive test result.

Of those participants who received negative QuickScreen test outcome, the proportion who were in the non-dyslexic group (i.e., sample negative predictive value); and of those participants who received a positive QuickScreen test outcome, the proportion who were in the dyslexic group (i.e., sample positive predictive value), are shown in Table 13.

Forty-nine percent (49.0%) of those participants with a negative QuickScreen test result were in the non-dyslexic group, and 95.3% with a positive QuickScreen test result were in the dyslexic group.

	QuickScreen Test Negative	QuickScreen Test Positive
Non-Dyslexic Group	49.0%	4.7%
Dyslexic Group	51.0%	95.3%

Table 13: Raw sample predictive values (negative for the non-dyslexic group and positive for the dyslexic group) for the QuickScreen test negative and test positive outcomes, based on the threshold associated with maximising the sensitivity + specificity, for the non-dyslexic group and the dyslexic group including "at risk" participants.

Overall, 82.5% ([147+751]/1088) of the QuickScreen test results were correct according to the non-dyslexic/dyslexic groups. These are the raw sample predictive values and overall accuracy, based on the observed sample prevalence, and do not reflect estimates for a random sample of the population nor those self-selecting for a QuickScreen test.

The diagnostic accuracy measures, estimated using the adjusted method (with adjusted logit confidence intervals) and assuming a 10% prevalence of dyslexia, based on the threshold associated with maximising the sensitivity + specificity, are shown in Table 14.

QuickScreen Test Result	Diagnostic Measure	Estimate	95% Confidence Interval
Positive	Sensitivity	82.9%	(80.3%, 85.2%)
	PPV	30.8%	(25.1%, 37.1%)
Negative	Specificity	79.3%	(72.9%, 84.5%)
	NPV	97.7%	(97.3%, 98.0%)
Overall	Accuracy	79.6%	(74.5%, 84.6%)

Table 14: Estimates of the diagnostic accuracy measures using the adjusted logit method, based on the threshold associated with maximising the sensitivity + specificity, for the non-dyslexic group and the dyslexic group including "at risk" participants (with 10% prevalence). PPV = Positive Predictive Value; NPV = Negative Predictive Value.

So, assuming an estimated prevalence of dyslexia in the population of 10%:

- The overall accuracy of the QuickScreen test (proportion of test results that are correct) is estimated to be 79.6%, with a 95% CI of 74.5% to 84.6%).
- The sensitivity (proportion of those with dyslexia that test positive) of the Quickscreen test is estimated to be 82.9% (95% CI: 80.3% to 85.2%).
- The specificity (proportion of those without dyslexia that test negative) is estimated to be 79.3% (95% CI: 72.9% to 84.5%).
- The positive predictive value (proportion of those with a positive test that have dyslexia) is estimated to be 30.0% (95% CI: 25.16% to 37.1%).
- The negative predictive value (proportion of those with a negative test that don't have dyslexia) is estimated to be 97.7% (95% CI: 97.3% to 98.0%).

We note that, in screening situations, the prevalence is almost always small and the positive predictive value low, even for a fairly sensitive and specific test. This is reflected in the estimated positive predictive value of 30.8% here, which is impacted by the assumed prevalence of dyslexia in the population. We'll see in the subsequent results below, that for a higher assumed prevalence of dyslexia, the positive predictive value is higher.

The diagnostic accuracy measures, again estimated using the adjusted method (with adjusted logit confidence intervals) but assuming a 78.8% prevalence of dyslexia, based on the threshold associated with maximising the sensitivity + specificity, are shown in Table 15.

QuickScreen Test Result	Diagnostic Measure	Estimate	95% Confidence Interval
Positive	Sensitivity	82.9%	(80.3%, 85.2%)
	PPV	93.7%	(91.8%, 95.2%)
Negative	Specificity	79.3%	(72.9%, 84.5%)
	NPV	55.6%	(51.6%, 59.5%)
Overall	Accuracy	82.2%	(79.9%, 84.3%)

Table 15: Estimates of the diagnostic accuracy measures using the adjusted logit method, based on the threshold associated with maximising the sensitivity + specificity, for the full non-dyslexic group including "at risk" participants (with 78.8% prevalence). PPV = Positive Predictive Value; NPV = Negative Predictive Value.

The estimates of the sensitivity and specificity are unaffected by the change in assumed prevalence of dyslexia. However, based on this higher estimate of dyslexia for participants who have self-identified to take the test:

- The overall accuracy of the QuickScreen test (proportion of test results that are correct) is estimated to be 82.2% (95% CI: 79.9% to 84.3%).
- The positive predictive value (proportion of those with a positive test that have dyslexia) is estimated to be 93.7% (95% CI: 91.8% to 95.2%).
- The negative predictive value (proportion of those with a negative test that don't have dyslexia) is estimated to be 55.6% (95% CI: 51.6% to 59.5%).

We note that for this higher assumed prevalence the positive predictive value is estimated to be much higher at approximately 94%. However, the negative predictive value has correspondingly decreased to 55.6%.

General Speed of Processing

Another area of research was to explore how the QuickScreen general speed of processing results vary between dyslexic and non-dyslexic participants. This analysis is based on the dyslexic and non-dyslexic groups only (i.e. not including the 'at risk' group of respondents).

Table 16 below shows a crosstabulation of the non-dyslexic/dyslexic group versus the general speed of processing results available from the QuickScreen test data.

	No Difficulties	Average	Difficulties	Total
Non-Dyslexic Group	56	90	38	184 (49.9%)
Dyslexic Group	17	100	68	185 (50.1%)
Total	73 (19.8%)	190 (51.5%)	106 (28.7%)	369 (100%)

Table 16: Crosstabulation of the non-dyslexic/dyslexic group versus the QuickScreen general speed of processing result (No Difficulties/Average/Difficulties).

A Fisher's exact test (on the data in Table 16) finds strong statistical evidence (p-value < 0.0001) of an association between the dyslexia group and the QuickScreen test result.

Table 17 below shows this data in percentage terms within each group. So, 30% of those without a previous diagnosis have no speed of processing difficulties compared with 9% for those with a previous diagnosis. At the other end of the scale, 37% of those with a previous diagnosis have difficulties, compared with 21% without a previous diagnosis.

	No Difficulties	Average	Difficulties
Non-Dyslexic Group	30.4%	48.9%	20.7%
Dyslexic Group	9.2%	54.1%	36.8%

Table 17: Sample specificity (non-dyslexic group row) and sensitivity (dyslexic group row) values for the QuickScreen general speed of processing results.

Looking at this in terms of speed of processing difficulties; of those with no speed of processing difficulties 77% were in the non-dyslexic group, whereas 64% of those with difficulties were in the dyslexic group (as shown in Table 18).

	No Difficulties	Average	Difficulties
Non-Dyslexic Group	76.7%	47.4%	35.8%
Dyslexic Group	23.3%	52.6%	64.2%

Table 18: Sample negative predictive values (the non-dyslexic group) and positive predictive values (the dyslexic group) for the QuickScreen general speed of processing results.

More detail is obtained from looking at the numerical score for general speed of processing rather than using the categorical result. There is strong statistical evidence (p < 0.0001) that the numerical

score is also associated with the non-dyslexic/dyslexic grouping. Non-dyslexic participants have a higher average (mean = 12.8, median = 13) speed processing score compared to those with dyslexia (mean = 10.5, median = 11), as shown in Table 19.

General Speed of Processing Score	Minimum	Lower Quartile (Q1)	Median	Mean	Upper Quartile (Q3)	Maximum
Non-Dyslexic Group	4	10	13	12.8	15	20
Dyslexic Group	1	8	11	10.5	13	19

Table 19: Summary statistics for the general speed of processing scores for the non-dyslexic/dyslexic groups.

These distribution results are also presented visually as boxplots[8] in Figure 7.

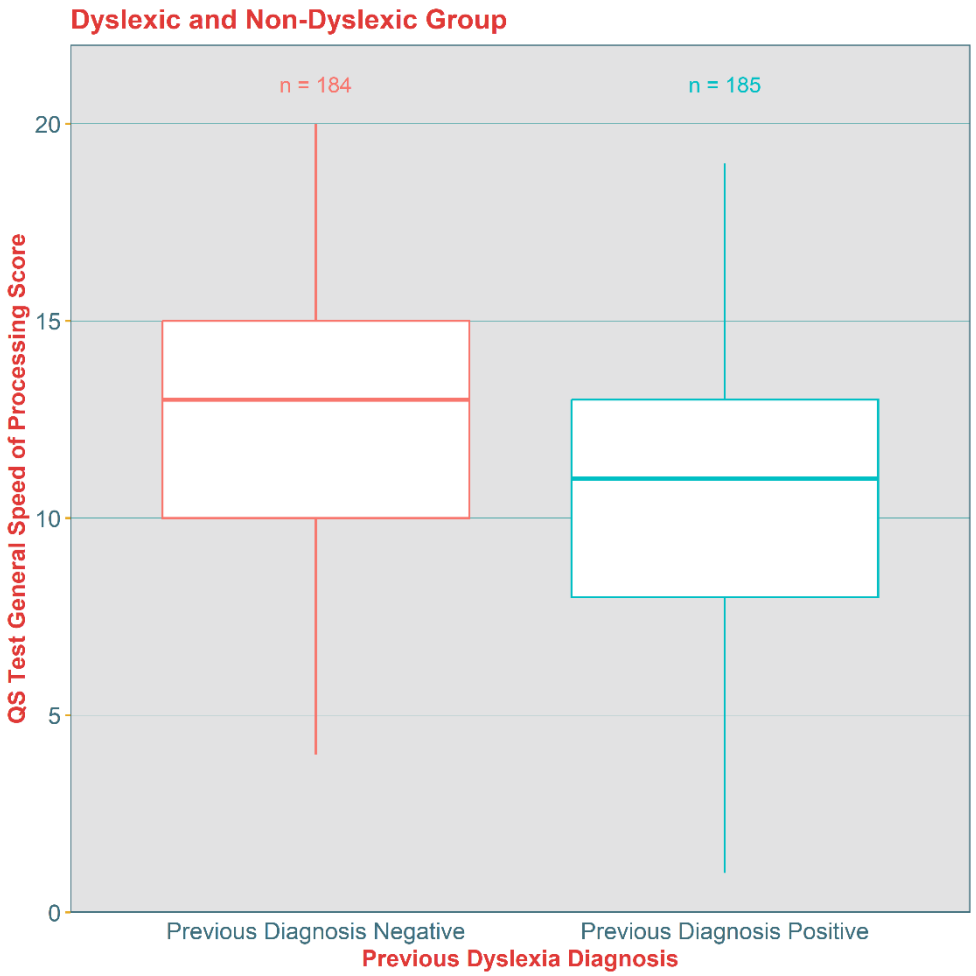

Figure 7: Boxplots of the general speed of processing scores by non-dyslexic/dyslexic group.

To explore the speed of processing results in more detail, we looked at how these relate to the dyslexia quotient.

As the speed of processing score is a component of the dyslexia quotient, we subtract the speed of processing score from the dyslexia quotient and use this 'adjusted' quotient in our analysis.

[8] https://select-statistics.co.uk/resources/glossary-page/#box-plot

We find clear evidence of an association between the processing speed disparity and the adjusted quotient. As shown in the scatterplot in Figure 8, for both those with and without a previous dyslexia diagnosis, the participants with a lower speed of processing score tend to have a higher dyslexia quotient (having removed the specific speed of processing component from the quotient itself) – in each case we find evidence of a negative correlation that is statistically significantly different from zero ($p < 0.001$ in both the dyslexic group and the non-dyslexic group).

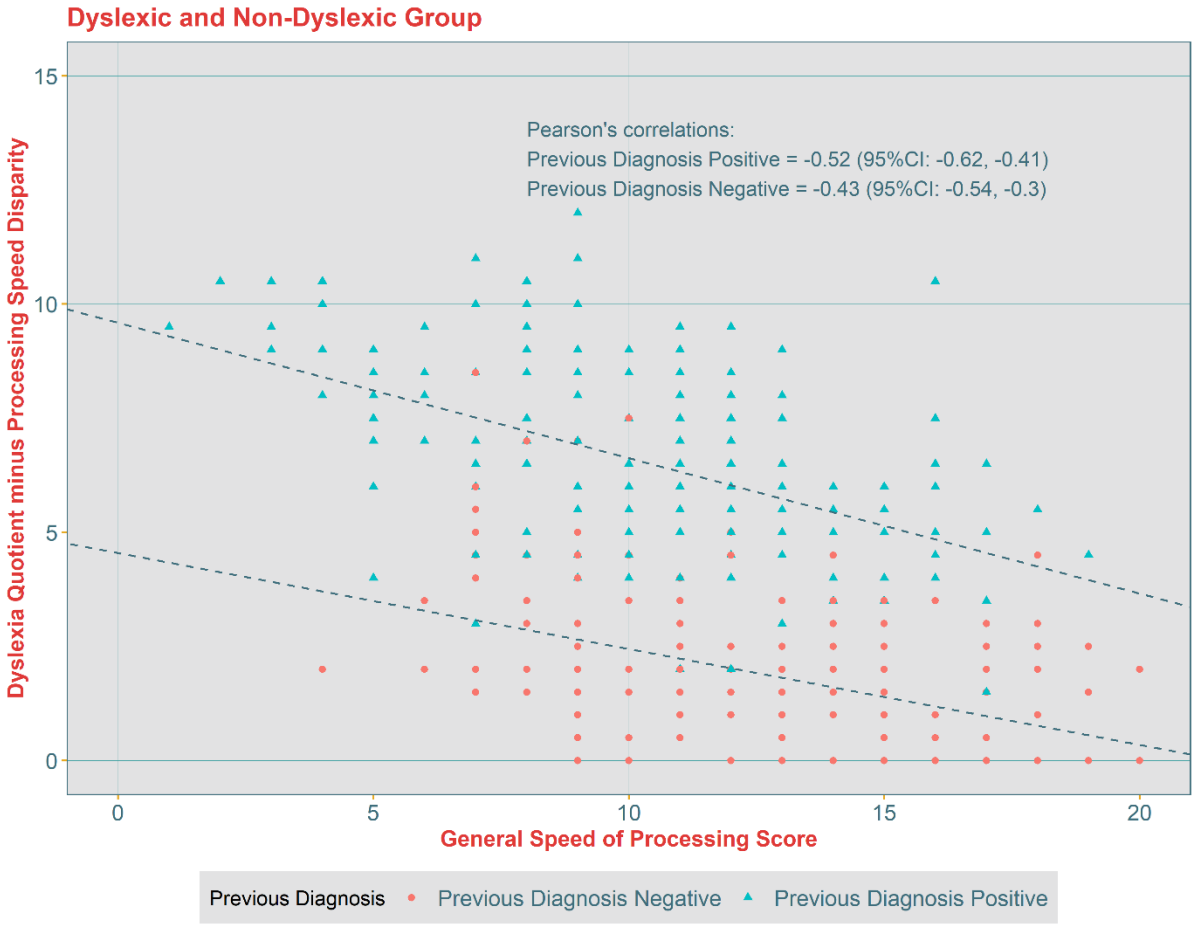

Figure 8: Scatterplot of the dyslexia quotient minus processing speed disparity versus general speed of processing score, for the dyslexic and non-dyslexic group, with fitted simple regression lines.

We also find evidence of a difference in the average dyslexia quotient minus processing speed disparity across the grouped general speed of processing results (No Difficulties, Average, Difficulties), overall and by non-dyslexic/dyslexic group. A higher quotient was observed on average for those with difficulties, followed by the average group, and then those with no difficulties ($p < 0.0001$ overall, for the dyslexic group and for the non-dyslexic group). Summary statistics for the dyslexia quotient minus processing speed disparity values by the dyslexic/non-dyslexic group and general speed of processing result are shown in Table 20. For example, overall, the median value for those with no processing speed difficulties was 1.5 compared with 6 for those with difficulties.

Dyslexia Quotient minus Processing Speed Disparity	General Speed of Processing Result	Min.	Lower Quartile (Q1)	Median	Mean	Upper Quartile (Q3)	Max.
Overall	No difficulties	0	0	1.5	2.07	3.5	6.5
	Average	0	1.5	4	3.95	6	10.5
	Difficulties	0	4	6	6.06	8.5	12
Non-Dyslexic Group	No difficulties	0	0	1	1.22	2	4.5
	Average	0	0.5	1.5	1.74	2.5	7.5
	Difficulties	0	1.625	2.75	3.09	4.5	8.5
Dyslexic Group	No difficulties	1.5	4.5	5	4.85	5.5	6.5
	Average	2	5	5.5	5.94	7	10.5
	Difficulties	3	6	8	7.71	9.5	12

Table 20: Summary statistics for the dyslexia quotient minus processing speed disparity overall and for the non-dyslexic/dyslexic groups by general speed of processing result.

These results are also visualised with boxplots showing the distributions of the dyslexia quotient minus the processing speed disparity values overall (Figure 9), and for the dyslexic and non-dyslexic groups (Figure 10), by general speed of processing result.

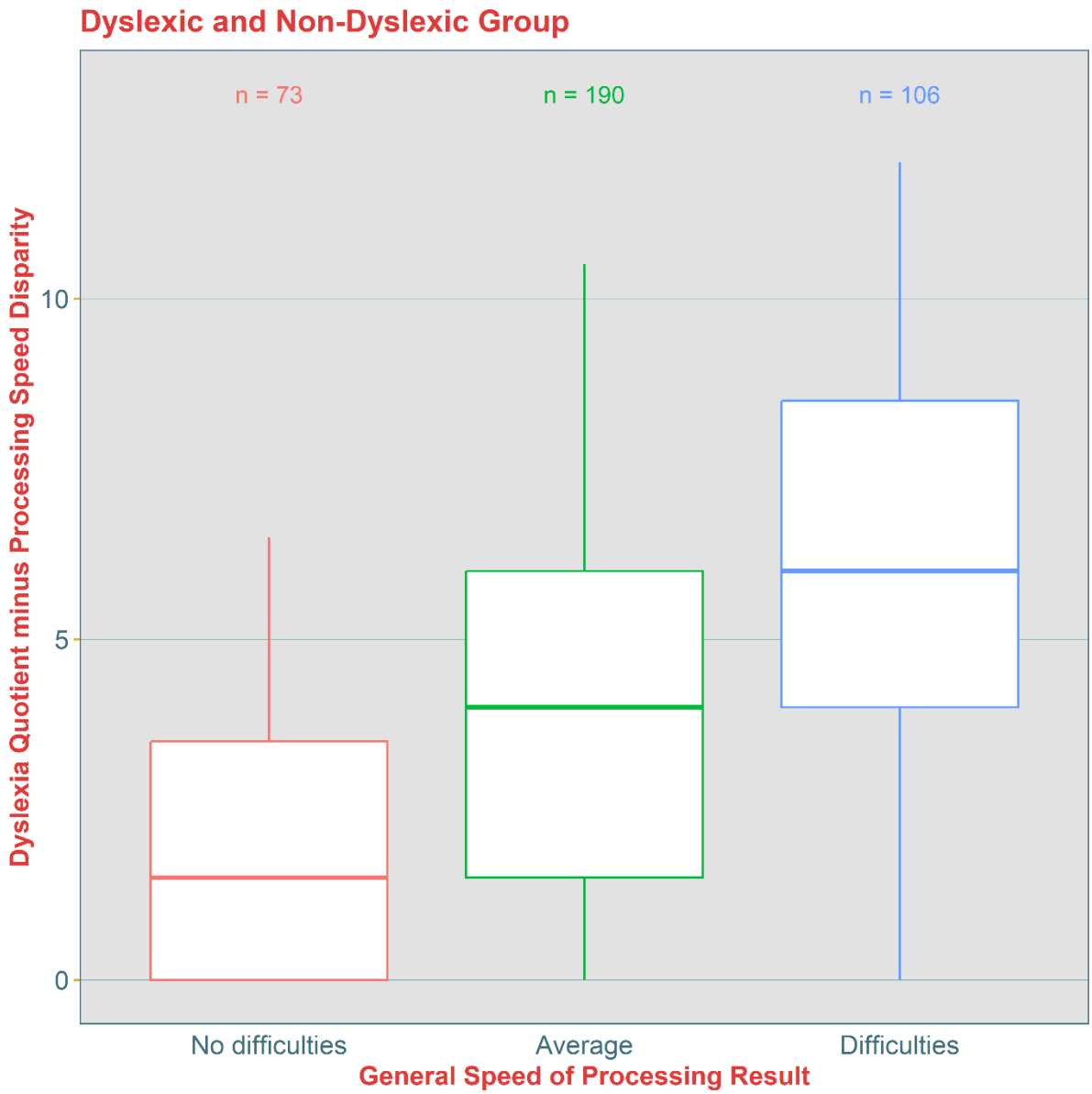

Figure 9: Boxplots of the dyslexia quotient minus processing speed disparity by general speed of processing result, for the dyslexic and non-dyslexic groups.

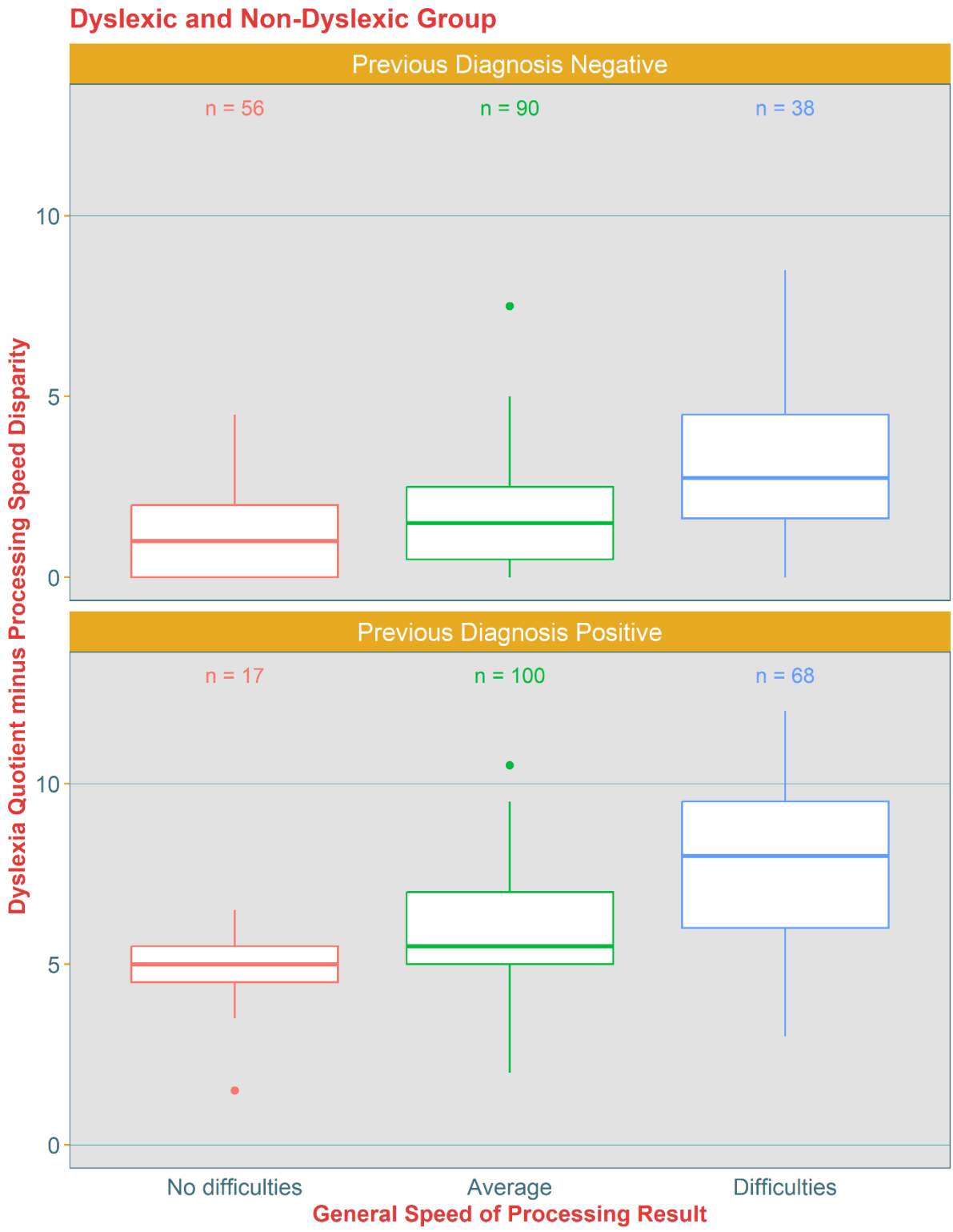

Figure 10: Boxplots of the dyslexia quotient minus processing speed disparity and general speed of processing result, for the dyslexic group and non-dyslexic group.

Potential Further Work

The analysis presented in this report provides an assessment of the current diagnostic accuracy of the QuickScreen dyslexia test and finds evidence of a high overall accuracy (at 86.5% when the prevalence in the population is estimated to be 10% and 92.4% when the prevalence is estimated to be 78.8%). Since the limitations of this study include that there are likely university educated respondents in the dyslexic group who are perhaps expected to be more or less well compensated, and therefore more or less challenging in which to detect the symptoms of dyslexia , further work could potentially be undertaken to expand upon this analysis to, for example, explore the performance achieved for different groups of participants who take the QuickScreen test.