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Intelligence measures as diagnostic tools for children with specific learning disabilities

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Author Contributions

D. Giofrè, E. Toffalini, and C. Cornoldi developed the study concept. E. Toffalini, G. Altoè, and D. Giofrè performed data analysis. All authors contributed to drafting the manuscript.

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Abstract

The assessment of intelligence has always been an essential part of the diagnostic process of children with specific learning disabilities (SLD). Recently, emphasis has been placed on the profile of intellectual strengths (e.g. in reasoning) and weaknesses (e.g., in working memory and processing speed). In this study, we compared the WISC-IV intellectual profile of 1,383 children with SLD to the normative data for typically developing children; in particular, we analyzed the predictive power of WISC-IV indexes and their discrepancies–especially the general ability index (GAI) vs. the cognitive proficiency index (CPI) or vs. the full-scale (FSIQ)–as markers of the SLD condition. Results showed that the intellectual profile in general, and the GAI-CPI or GAI-FSIQ discrepancy in particular, represents an effective criterion for differentiating between groups. Examining the underlying cognitive profile might be useful when dealing with children who have SLD, as discrepancies could be effectively used to support a diagnosis.

Keywords: Intelligence Quotient, IQ; Specific Learning Disability, SLD; Discrepancy; General Ability Index, GAI; Children.

Intelligence measures as diagnostic tools for children with specific learning disabilities.

Specific learning disabilities (SLD) are neurodevelopmental disorders with a biological origin that lead to persistent difficulties in the acquisition of specific academic skills. Different criteria have been proposed for the clinical diagnosis of SLD, but all include the consideration of children's intelligence. The discrepancy between a normal or high intellectual functioning and unexpectedly low academic achievement (i.e., the so-called intelligence-achievement discrepancy) has long been considered as the hallmark of SLD (U.S. Office of Education, 1977). Recently, the intelligence-achievement discrepancy has been sharply criticized primarily because cutoff-points are somewhat arbitrary (Tannock, 2013). Further, the dimensional nature of the distribution of intelligence and achievement scores–and thus of their discrepancy–has been stressed in recent scholarship, raising doubts about the usefulness of imposing any cutoff-point (Francis et al., 2005).

Another problem with the intelligence-achievement discrepancy hypothesis is that it regards intellectual functioning as a single global index (i.e. the intelligence quotient [IQ]). Recent formulations of intelligence describe this construct as composed of different factors (Horn & Cattell, 1966). These criticisms have led the recently published Diagnostic and Statistical Manual of Mental Disorders, 5th edition (DSM-5; American Psychiatric Association [APA], 2013) to prudently state that in children with SLD difficulties should be apparent "*in individuals who otherwise demonstrate normal levels of intellectual functioning*" (p.69). Apart from giving exclusion criterion of intellectual disability and recommending cautious interpretation of borderline cases, the DSM-5 adds that "*assessment of cognitive processing deficits is not required for diagnostic assessment*" (p.70; APA, 2013).

Many researchers believe that the examination of the different factors composing intelligence and their discrepancies can be especially relevant in the case of SLD. Research has shown that the average intellectual profile of children with this diagnosis differs from that of typically developing (TD) children, as it is characterized by highly heterogeneous scores (e.g., Cornoldi, Giofrè, Orsini, & Pezzuti, 2014; Poletti, 2016). This is consistent with the *specificity* hypothesis, which posits that

SLD is defined by a specific pattern of strengths and weaknesses (PSW) within the neuropsychological functioning and in academic outcomes, rather than by generalized cognitive problems (Compton, Fuchs, Fuchs, Lambert, & Hamlett, 2012). According to this view, the identification of a particular PSW within an individual's cognitive functioning can provide vital information for the diagnosis of SLD (Flanagan, Ortiz, & Alfonso, 2007).

The PSW approach, however, has been criticized by many authors. Critics point out that while it is well established that specific cognitive processes are related to academic achievement, this does not necessarily imply that cognitive patterns can provide reliable information for the diagnosis of SLD (Watkins, 2000). In fact, the problem of studies using PSW as a detector of SLD is that they often show poor discriminant power; i.e. they may have good specificity, but generally low sensitivity (Stuebing, Fletcher, Branum-Martin, & Francis, 2012). As a consequence, using clinically significant scores or differences as cutoff-points leads to a low rate of false positives, but also to a moderate or low rate of true positives (Kranzler, Floyd, Benson, Zaboski, & Thibodaux, 2016; Stuebing et al., 2012). However, the utility of cutoff-points has never been systematically studied on sufficiently large samples of children with SLD.

In this study, we examined to what extent the consideration of an individual's specific intellectual profile can assist in the diagnosis of SLD. To this aim, we used the *Wechsler Intelligence Scale for Children, 4th edition* (WISC-IV; Wechsler, 2003), which stands beside its recently updated 5th edition as the most widely used tool for assessing intelligence in children in many countries (Evers et al., 2012). Previous attempts, conducted using former versions of the WISC battery, led to unsatisfactory results (e.g., Kavale & Forness, 1984; Watkins, Kush, & Glutting, 1997). However, the WISC-IV seems promising as it differentiates between measures of general ability and other aspects–such as working memory and processing speed–that are often impaired in children with SLD (Cornoldi et al., 2014). In fact, the consideration of the intellectual profile as it is measured by the WISC-IV battery can be particularly useful for the assessment of children with SLD (Fiorello et al., 2007). In the present study, we examined how indexes derived from the WISC-IV battery could predict the probability that an individual would have an SLD diagnosis.

The WISC-IV intellectual profile of children with SLD differs from the profile of TD children. Children with SLD are characterized by higher scores in verbal comprehension (VCI) and perceptual reasoning (PRI), and markedly lower scores in working memory (WMI) and processing speed (PSI) indexes (Cornoldi et al., 2014; Poletti, 2016). This implies that the general ability index (Prifitera, Saklofske, & Weiss, 2008), which includes only the verbal and perceptual indexes (VCI and PRI), is on average higher than the full-scale intelligence quotient (FSIQ), which includes all indexes, and in particular it is higher than the cognitive proficiency index (CPI; Saklofske, Coalson, Raiford, & Weiss, 2010), which includes only WMI and PSI. This index is particularly important for children with SLD, as the abilities that comprise GAI (VCI and PRI) are more strongly related to the *g*-factor in such children, compared to typically developing children (Giofrè & Cornoldi, 2015). In fact, it has been suggested that the GAI may be a valid alternative way of summarizing the overall intellectual functioning of children with SLD (Saklofske, Prifitera, Weiss, Rolfhus, & Zhu, 2005). Therefore, the discrepancy between the two broad indexes, i.e. GAI and CPI, may be of particular relevance in the case of children with SLD.

In the present study, we analyzed data from a large dataset of 1,383 SLD children. All children in the set had a clinical diagnosis of SLD, obtained using the ICD-10 International Coding System. The children’s intelligence was assessed using the 10 basic subtests of the WISC-IV scale. We chose to treat SLD as a single category–as it is also suggested by the DSM-5–but we are aware that different SLD subtypes may present systematic differences in their average intellectual profiles (Toffalini, Giofrè, & Cornoldi, 2017). Normative data, simulated from the Italian WISC-IV manual, was compared to the data of SLD children. We examined whether we could discriminate between the two groups (i.e., SLD and TD) using any of the following measures: a linear combination of the four main indexes of the WISC-IV (i.e. VCI, PRI, WMI, and PSI), the GAI-CPI discrepancies, or the discrepancies within the GAI-FSIQ.

Method

Participants

Data on 1,383 children with SLD was collected under the sponsorship of the Italian Association for Learning Disabilities (AIRIPA). Data were provided by a group of 27 licensed psychologists, experts in the diagnosis and treatment of SLD, located in 8 major Italian regions. A subset of this data had been included in previously published articles (Cornoldi et al., 2014; Giofrè & Cornoldi, 2015; Giofrè, Stoppa, Ferioli, Pezzuti, & Cornoldi, 2016; Toffalini et al., 2017); however, these articles did not address the issue examined in the present study. All children received a diagnosis within the F81 category (i.e., specific developmental disorders of scholastic skills) of the ICD-10 International Coding System (World Health Organization, 1992), which is the classification system generally consulted in Italy for SLD. Following the guidelines indicated by the National Italian Consensus Conference on SLD published by the Italian Ministry of Health (Istituto superiore di sanità, 2011), all diagnosed children met the following criteria: 1) academic achievement in at least one specific area below the 5^{th} percentile or 2 SDs below average, as assessed using relevant standardized tests, 2) any major influence of known socio-cultural, educational, emotional, intellectual, sensory and neurological problems was eliminated as the cause of the low academic achievement.

Children with SLD were in a range between 7 and 16 years of age (M_{age} = 11.46 [*SD* = 2.44]; 39% females). According to the ICD-10 coding system, cases were categorized as follows: 346 children with reading disorder (F81.0); 147 children with spelling disorder (F81.1); 93 children with specific disorder of arithmetical skills (F81.2); 501 children with mixed disorder of scholastic skills (F81.3); 75 children with other developmental disorders of scholastic skills (F81.8); 19 children with developmental disorder of scholastic skills, unspecified (F81.9); the remaining 295 children, who received more than one diagnosis within the F81 category. Cases with other comorbid neuropsychological disorders (e.g., attention-deficit hyperactivity disorders, developmental coordination disorder) were excluded in a preliminary screening.

Instrument

The Italian adaptation of the WISC-IV (Orsini, Pezzuti, & Picone, 2012) with the four main indexes (VCI, PRI, WMI, and PSI), the GAI, the CPI and the FSIQ was used.

Data analysis

All analyses were conducted using the *R* software (R Core Team, 2014). Logistic regression models were used to establish the predictive (i.e., discriminating) power of the intellectual profile on the SLD vs. TD condition as a binomial response variable. Analyses were conducted in two phases. First, the predictive power of the entire WISC-IV profile was tested by entering the four main indexes as independent predictors. Further, the simple GAI-CPI difference was entered as a single predictor in the model. The GAI-FSIQ difference (a conceptually equivalent alternative) was also tested.

The coefficients of the model as well as a receiver operating characteristic (ROC) curve and its related area under the curve (AUC, which is a measure of a classifier performance; Fawcett, 2006), were estimated using a Monte Carlo method on simulated data. AUC was calculated using the “pROC” *R* package (Robin et al., 2011). In particular, the analysis was repeated 100,000 times on intellectual profiles simulated on the basis of the correlation matrix and the vectors of means and standard deviations of the 10 basic subtests available for both SLD and TD children. To produce simulated data on TD children, we used the correlation matrix and the descriptive statistics reported in the Italian version of the WISC-IV (Orsini et al., 2012). The Italian manual reports data from 2,200 children between 6 and 16 years of age, and excludes any case with a diagnosis of SLD. The normality of the distributions of all 10 basic subtests was assumed, as it seems appropriate for intelligence measures. To obtain plausible confidence intervals for the coefficients and the AUCs, 1,383 SLD profiles and 2,200 TD profiles were generated for each iteration. As intellectual disability is an exclusion criterion for SLD, in order to simulate a realistically comparable TD population, we automatically and *a priori* excluded TD profiles with FSIQ < 70. After the 100,000 iterations, the median value was reported as the final estimate for coefficients and AUCs. We also calculated 95% confidence intervals as the range of values between the 2.5th percentile and the 97.5th percentile. The odds ratios (OR)–calculated as the change in odds (of an observation having been generated from the SLD profile) for an increase of one standard deviation (calculated on the TD population) of the predictor–were reported as a measure of the effect size. Finally, the abovementioned logistic regression models were compared through the *Bayes Factor* (BF; Wagenmakers, 2007), an index that compares alternative models in terms of their relative likelihood of having generated the observed data, and that balances the fit of the model with its complexity.

Results

Table 1 reports the correlations and descriptive statistics for all 10 basic subtests and composite indexes of the WISC-IV, separately computed on simulated data for SLD and TD children. Statistics calculated on simulated SLD data were obviously identical to those calculated from real data, whereas statistics calculated on simulated TD data slightly differed (for correlations, all differences < |.04|; for descriptive statistics, consider normative data as the reference), due to the fact that profiles with FSIQ < 70 were removed.

Table 1 about here

In phase 1, a logistic regression model having the four main WISC-IV indexes (i.e. VCI, PRI, WMI, and PSI) as the predictors, and group (SLD vs. TD; reference category is TD) as the outcome, was defined. In this model, for VCI: B = .021, OR^{SD} = 1.353, 95% CI (1.237–1.480); for PRI: B = .041, OR^{SD} = 1.799, 95% CI (1.639–1.981); for WMI: B = -.069, OR^{SD} = .365, 95% CI (.331–.401); for PSI: B = -.036, OR^{SD} = .588, 95% CI (.541–.638); AUC of the ROC curve = .777, 95% CI (.761–.792). Therefore, AUC indicated moderate predictive power. Note that VCI and PRI had positive coefficients, and WMI and PSI had negative coefficients, predictably indicating opposite effects on the probability of having SLD. Also note that no 95% CI included 1, suggesting statistically significant effects of all predictors.

In phase 2, a logistic regression model was defined, having the GAI-CPI difference as the predictor, and the group as the outcome. In this model, for the GAI-CPI difference: *B* = .064, OR^{SD} = 2.506, 95% CI (2.320–2.716); AUC of the ROC curve = .748, 95% CI (.731–.764). In terms of sensitivity and specificity of the test, here are some examples using different critical cutoffs: with GAI-CPI ≥ 6, sensitivity = .700, specificity = .659; with GAI-CPI ≥ 14, sensitivity = .525, specificity = .833; with GAI-CPI ≥ 20, sensitivity = .363, specificity = .917. The plot of this logistic model is presented in Figure 1A; it shows the probability that a child has SLD as a function of the GAI-CPI difference, setting an a priori percentage probability of 5% (i.e. a reasonable prevalence ratio of SLD within the general population). Figure 1B shows the associated ROC curve.

Finally, given that CPI, unlike GAI or FSIQ, is not commonly used in clinical practice, we also tested the simple GAI-FSIQ difference as a predictor of the group. In this model: *B* = .177, OR^{SD} = 2.697, 95% CI (2.493–2.938); AUC of the ROC curve = .762, 95% CI (.746–.778).

Figure 1 about here

The AUCs suggested moderate predictive power in all models. The median *BF* for the comparison between the model in phase 1 (entire profile) and models in phase 2 (GAI-CPI and GAI-FSIQ) was $1.71*10^{-33}$ for GAI-CPI, and $4.93*10^{-16}$ for GAI-FSIQ, thus strongly favoring the model using the entire profile over both alternatives. The median *BF* for the comparison between the models that used GAI-CPI vs. GAI-FSIQ as the predictors was $2.68*10^{17}$, strongly favoring the latter (possibly due to the higher reliability of the FSIQ as compared to the CPI). However, it must be noted that the differences among alternative models are modest from a clinical point of view (ΔAUCs < .029).

As our SLD sample included some residual and unspecified cases (F81.8, F81.9, and cases receiving more than one diagnosis) that could differ from the most common SLD subtypes (dyslexia, spelling disorder, dyscalculia, and mixed), we also ran an analysis excluding these cases. The results, obtained using the remaining 1,087 cases, were very similar[1].

Additional analyses

We offered examples of probabilities that SLD would be associated with different levels of the GAI-CPI discrepancy. In Italy SLD is diagnosed in general neuropsychological treatment centers; 30-50% of children who go to these centers for help eventually receive a diagnosis of SLD (Istituto superiore di sanità, 2011). Table 2 shows the estimated probabilities of a child having SLD as a function of different levels of GAI-CPI and GAI-FSIQ discrepancies, considering a priori probabilities of 30% and 50%. For example, if the GAI-CPI, or the GAI-FSIQ, discrepancy is large and negative, the presence of a SLD is highly unlikely. Conversely, if the GAI-CPI or the GAI-FSIQ discrepancy is large and positive, the presence of a SLD is very probable (Table 2).

Table 2 about here

It can be argued that SLD is just an umbrella term and that many different conditions exist under this category. In fact, it has been shown that the cognitive profile of children with SLD can be quite heterogeneous when the four principal indexes of the WISC-IV are considered (Poletti, 2016; Toffalini et al., 2017). Although differences may emerge when using the four main indexes, when the GAI and CPI are considered, the performance of children with SLD is quite homogenous and does not change across different SLD subtypes (Toffalini et al., 2017). In fact, if we only consider the SLD group and the GAI and CPI, the interaction term between subtypes and index is not statistically significant, $\chi^2(5) = 2.74$, $p = .74$.[2] This confirms that children within the SLD category generally present with a similar pattern with a higher GAI than the CPI (see also Toffalini et al., 2017 on this point).

Discussion

This study aimed to test whether the WISC-IV might support a SLD diagnosis. In particular, we tested the four main indexes of the WISC-IV (VCI, PRI, WMI, and PSI), and two measures of discrepancy, i.e. between GAI and CPI and between GAI and FSIQ, as potential “diagnostic markers" of the SLD condition. As for both the GAI-CPI and the GAI-FSIQ discrepancy, our results showed that sensitivity and specificity values were adequate, although not particularly high. Considering the cognitive profile discrepancy criteria alone is therefore not sufficient, as the predictive power is only moderate. However, these criteria seem useful for supporting the diagnosis of children with SLD. As for the predictive power of the four principal indexes, we found that they also had a moderate predictive value, which was slightly higher than the predictive power of the GAI-CPI or the GAI-FSIQ discrepancies. Notably, all four WISC-IV indexes could be considered as independent significant predictors of the group. However, in terms of practical application, the predictive performance of a linear combination of the four main indexes was not substantially higher than the predictive performance of the GAI-CPI or the GAI-FSIQ discrepancy criteria.

While sensitivity and specificity are calculated with regard to a fixed cutoff, there is not such a cutoff in reality. It is unlikely that a child in the SLD group has a large negative GAI-CPI discrepancy, and at the same time, it is unlikely that a child in the TD group has a large positive GAI-CPI discrepancy; the same is true for the GAI-FSIQ discrepancy. Therefore, observing discrepancy scores allows us to estimate the likelihood that one child does or does not belong to the control (i.e. TD) group. This likelihood can also be used for confirming a diagnosis, particularly in uncertain cases. In fact, calculating such discrepancy criteria is not very difficult, and could be easily adopted as a routine in the clinical practice.

It has been suggested that IQ scores may be more useful compared to the four principal indexes (Watkins & Smith, 2013). However, the evaluation of intelligence generally requires the use of different measures assessing diverse components of intelligence (e.g., Carroll, 1993). In particular, the GAI index, obtained from the WISC-IV, seems to be highly reliable (Saklofske et al., 2005), taking into account the most reliable indexes of the WISC-IV (i.e., PRI and VCI) (Watkins & Smith, 2013). In the case of our study, we showed that severe discrepancies between GAI and CPI are very unlikely in the TD group, while they are common in children with SLD (Cornoldi et al., 2014). It can be argued that the exclusion of WMI and PSI from the intellectual profile can produce an overestimation of the intellectual potential of children with SLD (Weiss, Saklofske, Holdnack, & Prifitera, 2016). We believe that GAI and CPI are both important and should be reported along with the FSIQ. In fact, contrasting the GAI with the CPI (or the FSIQ) can provide useful information for the assessment and the treatment of children with SLD.

In the present study we treated children with SLD as a single group, which was compared to a group of TD children. This decision is in line with the DSM-5 in which a single diagnostic category for SLD was recently proposed (APA; 2013). However, the nature of SLD (unitary vs. decomposable disorder) has been the object of scientific debate (Tannock, 2013). For example, it has been shown that different SLD subtypes present heterogeneous profiles at the WISC-IV when the principal indexes are considered (Poletti, 2016; Toffalini et al., 2017). Although there are some differences in the cognitive profile, SLD subtypes share substantial similarities in their average intellectual profiles. The most notable and consistent of these similarities is the discrepancy between GAI and CPI indexes (Toffalini et al., 2017). In terms of diagnostic power, the GAI-CPI (or the GAI-FSIQ) discrepancy has similar predictive value compared to the linear combination of the four main indexes, and is a more streamlined, easy-to-use metric.

Though it contains some insightful findings, the present paper also has some limitations. While the within-profile discrepancies could provide some useful information to support a diagnosis of SLD, they should never be considered as the basis of it, and should not be used in isolation. In particular, not only do the discrepancies within the intellectual profile have a moderate predictive power, but they might also be found in other neurodevelopmental disorders. For example, attention deficit hyperactivity disorder (ADHD) and autistic spectrum disorder often present a positive GAI-CPI discrepancy (APA, 2013; Calhoun & Mayes, 2005). It should be noted that in a large majority of these neurodevelopmental disorder cases, learning disability also occurs (Calhoun & Mayes, 2005). In our study, co-morbid cases of ADHD, autism, and any other neurodevelopmental disorder were not included in the dataset. Future research should try to assess the effectiveness of intellectual or neuropsychological profile patterns in distinguishing between different types of neurodevelopmental disorders. Further research should also conduct similar analyses on cases of other neurodevelopmental disorders typified by specific patterns of intellectual strengths and weaknesses. For example, separately considering the GAI and FSIQ may be important for children with intellectual disability (Koriakin et al., 2013; Lanfranchi, 2013). Furthermore, children with specific language impairment, ADHD, autism spectrum disorder, and developmental coordination disorder often present weaknesses in working memory and in processing speed (Calhoun & Mayes, 2005; Dickerson & Susan, 2008; Gomez, Vance, & Watson, 2016; Sumner, Pratt, & Hill, 2016; Wechsler, 2003). Further research using real data and not simulated data for typically developing children could also build on this study in beneficial ways.

In conclusion, while the specific intellectual profile should not be used as a single diagnostic test of SLD, it may represent an effective marker of this neurodevelopmental condition. Evidence on the specificity of the SLD intellectual profile should also be considered to understand the nature of this condition and the best way to treat it in clinical practice, introducing for example clinical and educational practices for children with SLD that do not rely to an excessive extent on speed and on the maintenance of an excessive amount of information in working memory.

Footnote

[1] The results excluded from the sample all cases diagnosed with F81.8, F81.9, and also excluded cases receiving more than one diagnosis (remaining SLD sample: *N* = 1087). Logistic regression models having the four main WISC-IV indexes as the predictors and group as the outcome: for VCI: *B* = .019, OR^{SD} = 1.338, 95% CI (1.209–1.483); for PRI: *B* = .041, OR^{SD} = 1.804, 95% CI (1.633–1.998); for WMI: *B* = -.070, OR^{SD} = .407, 95% CI (.371–.445); for PSI: *B* = -.035, OR^{SD} = .615, 95% CI (.564–.669); AUC of the ROC curve = .775, 95% CI (.758–.792). Logistic regression models having the GAI-CPI difference as the predictor and the group as the outcome: *B* = .063, OR^{SD} = 2.609, 95% CI (2.389–2.862); AUC of the ROC curve = .741, 95% CI (.723–.759). Logistic regression models having the GAI-FSIQ difference as the predictor and the group as the outcome: *B* = .174, OR^{SD} = 2.811, 95% CI (2.569–3.092); AUC of the ROC curve = .757, 95% CI (.739–.774). The median *BF* for the comparison between the model in phase 1 (entire profile) and models in phase 2 (GAI-CPI and GAI-FSIQ) was $3.26*10^{-32}$ for GAI-CPI, and $1.74*10^{-16}$ for GAI-FSIQ, thus strongly favoring the model using the entire profile over both alternatives. The median *BF* for the comparison between the models having GAI-CPI vs. GAI-FSIQ as the predictors was $4.90*10^{15}$, strongly favoring the latter (possibly due to the higher reliability of the FSIQ as compared to the CPI).

[2] The interaction was tested using the likelihood ratio test for nested models comparing mixed-effects linear models; children were treated as random effects.

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Table 1.

Correlations, means, and standard deviations in the standardized scores for the 10 basic subtests, the composite WISC-IV indexes, and the GAI-FSIQ discrepancy, in SLD (above the diagonal) and TD (below the diagonal; N = 2,200) profiles.

	SI	VC	CO	BD	PCm	MR	DS	LN	CD	SS	VCI	PRI	WMI	PSI	GAI	CPI	FSIQ	GAI-CPI	GAI-FSIQ	*M*	*SD*
SI	-	.58	.46	.32	.33	.29	.22	.22	-.01	.11	.82	.42	.26	.06	.75	.20	.67	.51	.36	10.21	2.97
VC	.60	-	.51	.26	.24	.25	.20	.21	.04	.06	.83	.34	.25	.06	.72	.20	.63	.48	.34	10.31	2.87
CO	.48	.57	-	.19	.21	.16	.16	.20	.03	.06	.82	.25	.22	.05	.66	.17	.58	.45	.32	10.90	3.27
BD	.35	.29	.24	-	.26	.43	.13	.20	.08	.19	.31	.74	.20	.16	.61	.23	.57	.35	.23	10.29	2.84
PCm	.40	.38	.32	.31	-	.32	.11	.19	.04	.14	.32	.71	.18	.10	.59	.18	.53	.38	.27	11.02	2.94
MR	.38	.37	.26	.39	.40	-	.17	.27	.12	.23	.28	.79	.27	.20	.62	.30	.61	.30	.17	10.63	3.05
DS	.32	.30	.21	.23	.25	.26	-	.38	.10	.08	.23	.19	.83	.10	.25	.58	.45	-.25	-.37	8.18	2.55
LN	.32	.35	.27	.26	.32	.32	.40	-	.13	.16	.26	.29	.83	.17	.33	.63	.53	-.23	-.36	8.57	2.57
CD	.11	.10	.12	.23	.08	.17	.12	.16	-	.45	.03	.11	.14	.86	.08	.68	.36	-.49	-.59	8.37	2.90
SS	.24	.20	.19	.27	.21	.23	.17	.21	.44	-	.09	.25	.15	.84	.20	.67	.45	-.38	-.50	9.28	2.75
VCI	.83	.86	.82	.35	.44	.40	.33	.37	.13	.25	-	.40	.29	.07	.86	.23	.76	.58	.41	102.86	15.04
PRI	.49	.46	.36	.75	.75	.79	.32	.39	.21	.31	.52	-	.29	.21	.81	.32	.76	.46	.29	104.04	14.33
WMI	.38	.39	.28	.29	.34	.34	.84	.83	.17	.23	.42	.43	-	.17	.35	.72	.59	-.29	.44	90.32	12.94
PSI	.20	.18	.18	.29	.17	.24	.17	.22	.85	.85	.22	.31	.23	-	.16	.78	.48	-.50	.64	93.03	14.07
GAI	.77	.77	.69	.62	.67	.67	.37	.43	.19	.32	.88	.86	.48	.30	-	.32	.91	.63	.43	103.79	13.85
CPI	.37	.36	.30	.38	.32	.37	.64	.67	.66	.69	.41	.47	.78	.79	.50	-	.68	-.54	-.72	89.80	12.80
FSIQ	.70	.69	.61	.60	.61	.63	.54	.60	.43	.53	.80	.81	.69	.56	.92	.80	-	.24	.01	98.08	12.53
GAI-CPI	.39	.40	.38	.24	.34	.30	-.27	-.24	-.47	-.38	.47	.38	-.30	-.50	.49	-.51	.12	-	.97	14.21	15.51
GAI-FSIQ	.18	.20	.20	.06	.16	.11	-.43	-.41	-.59	-.53	.23	.15	-.50	-.66	.22	-.74	-.18	.96	-	5.71	5.84
M	10.12	10.12	10.11	10.10	10.11	10.11	10.09	10.10	10.07	10.09	100.68	100.68	100.59	100.49	100.77	100.67	100.83	.09	-.06		
SD	2.91	2.91	2.93	2.93	2.93	2.93	2.94	2.93	2.97	2.95	14.42	14.41	14.57	14.71	14.24	14.43	14.12	14.35	5.61		

Note. WISC-IV = Wechsler Intelligence Scale for Children; SLD = Specific Learning Disorder; TD = Typically Developing; SI = Similarities; VC = Vocabulary; CO = Comprehension; BD = Block Design; PCn = Visual puzzles; MR = Matrix Reasoning; DS = Digit Span; LN = Letter-Number sequencing; CD = Coding; SS = Symbol Search; VCI = Verbal Comprehension Index; PRI = Perceptual Reasoning Index; WMI = Working Memory Index; PSI = Processing Speed Index; GAI = General Ability Index; FSIQ = Full Scale Intelligence Quotient; *M* = mean; *SD* = standard deviation.

Table 2.
Example of estimated probabilities (in percentage) of a child having SLD given different GAI-CPI and GAI-FSIQ discrepancies, with an a priori probability of 30% or 50%.

GAI-CPI discrepancy										
A priori probability: 30%										
Scatter	*- 30*	*- 15*	*- 6*	*0*	*6*	*15*	*20*	*30*	*35*	*50*
Prob. %	3.8	9.3	15.6	21.3	28.6	41.7	49.7	65.3	72.2	87.3
A priori probability: 50%										
Scatter	*- 30*	*- 15*	*- 6*	*0*	*6*	*15*	*20*	*30*	*35*	*50*
Prob. %	8.7	19.8	30.4	39.0	48.3	62.3	69.4	81.0	85.4	93.8
GAI-FSIQ discrepancy										
A priori probability: 30%										
Scatter	*- 12*	*- 6*	*- 3*	*0*	*3*	*6*	*9*	*12*	*18*	*24*
Prob. %	3.5	9.0	14.1	21.4	31.1	42.8	55.4	67.3	85.0	94.0
A priori probability: 50%										
Scatter	*- 12*	*- 6*	*- 3*	*0*	*3*	*6*	*9*	*12*	*18*	*24*
Prob. %	8.1	19.2	28.0	39.0	51.3	63.3	73.9	82.3	92.6	97.1

Note. A priori probabilities of 30% or 50% may reasonably correspond to the suspect of a child having SLD once he/she enters a clinical center to seek professional attention. Note that an *a priori* probability must always be defined.

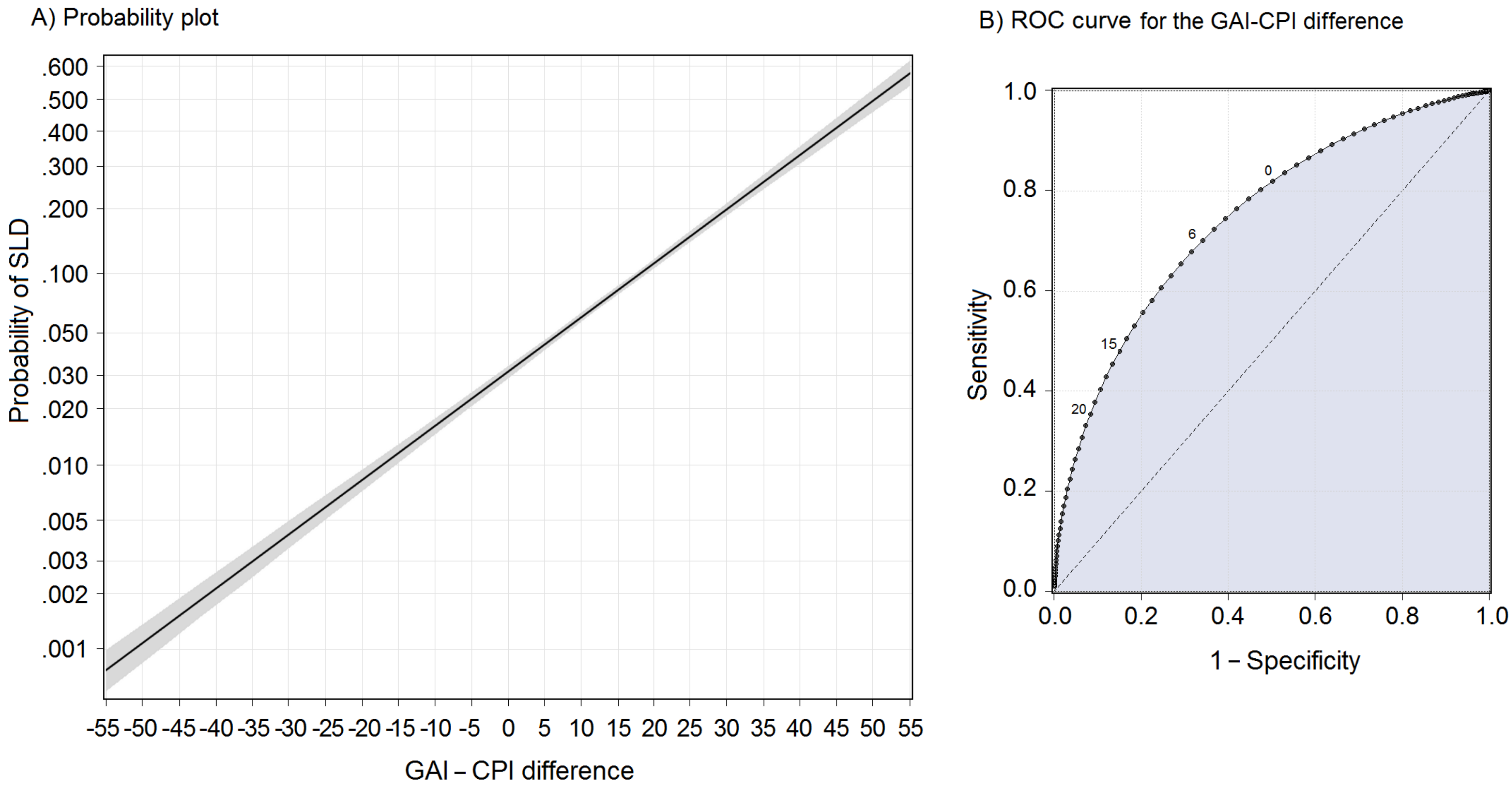

Figure 1. A) The plot of the logistic regression model having the GAI-CPI difference as the predictor and group as the outcome, with B) Receiver Operating Characteristic (ROC) curve associated with the model.