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Factor structure of the Spanish WAIS-III

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The Spanish version of the WAIS-III scale was published two year after the American one only. Taking into account the polemic about the factor structure of the previous versions (WAIS, and WAIS-R), it is critical to test what this new scale is assessing. Several structural models were analysed in the total sample (N = 1369), and in every normative age group through confirmatory factor analysis procedures. A model with four first-order factors (Verbal, Perceptual Organisation, Working Memory and Processing Speed) presents the best fit in all samples. When a second-order factor (identified with the *g* factor) is added to this model, the fit indexes also show acceptable values. Results support that *g* would be the main cognitive ability assessed by the WAIS-III. Implications for the scores computed after the scale (Total IQ, Verbal IQ, Performance IQ, and four cognitive indexes) are discussed.

Estructura factorial de la versión española del WAIS-III. Tan solo dos años después de la publicación en EE.UU. de la tercera versión de la escala Wechsler para adultos (WAIS-III), se adaptó dicha escala en España. Teniendo en cuenta la polémica sobre la estructura factorial de las versiones previas, es necesario comprobar qué factores está evaluando la nueva escala. Con este objetivo diversos modelos estructurales fueron ajustados tanto en la muestra total (N = 1369) como en cada grupo de edad. El modelo con cuatro factores de primer orden (Verbal, Organización perceptiva, Memoria de trabajo y Velocidad de procesamiento) obtuvo el mejor ajuste en todas las muestras. Por su parte, cuando se añadía un factor de segundo orden (identificado con *g*) al modelo anterior, los índices de ajuste presentaban valores considerados aceptables. En general, los resultados avalan la conclusión de que *g* es la principal aptitud cognitiva evaluada por la versión española del WAIS-III. Se discuten las implicaciones sobre las puntuaciones obtenidas a partir de la escala (CI total, CI verbal, CI manipulativo así como cuatro índices cognitivos).

Wechsler's scales (WPPSI, WISC, WAIS and their successive versions) are probably the psychometric instruments most used to assess cognitive abilities. Nevertheless, they have been continuously criticised due to the instability of the extracted factors, and the lack of agreement regarding their number and nature (Caruso & Cliff, 1998; Geary, & Whitworth, 1988; Kamphaus, Benson, Hutchison, & Platt, 1994; O'Grady, 1989; O'Grady, 1990). In fact, it has been claimed that they should become extinct (Carroll, 1993; Frank, 1983).

Focusing on WAIS scales (WAIS, WAIS-R, and WAIS-III), different structures with one (O'Grady, 1983), two (Verbal and Performance factors; Wechsler, 1955; Siegert, Pattern, Taylor, & McCormick, 1988), or three factors (Verbal Comprehension, Perceptual Organisation, and Freedom from Distractibility; Allen and Thorndike, 1995; Silverstein, 1985) have been defended. Caruso and Cliff (1998) suggest that divergences on how many factors should be extracted, as well as methodological pitfalls, are responsible of such conflictive results. They conclude that the one and two-factor solutions are both plausible, whereas the third factor is not replicable across age groups and, therefore, it is a questionable factor.

The aim of the current study is to look into the factor structure of the Spanish version of the WAIS-III. Confirmatory factor analysis will be conducted in order to compare different hypothesised models on the grounds of well-known fit indexes (Bollen, 1989).

Method

Participants

The Spanish standardisation sample of the WAIS-III (N= 1369; TEA, 1999)) was analysed in the present study. The six normative age groups (in years) and the corresponding N (in parentheses) are: 16-19 (163); 20-24 (153); 25-34 (272); 35-54 (408); 55-69 (237) y 70-94 (136). No larger differences than 3% were found between the standardisation sample, and the Spanish census in the percentages of sex, age, residence (urban, intermediate, rural), educational level, and geographic location (Seisdedos & Corral, 1999). So, the standardisation sample is representative of the Spanish population.

Instrument

The WAIS-III is an individually administered cognitive scale, shaped by 14 subtests: Vocabulary, Similarities, Information,

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Comprehension, Arithmetic, Digit span, Letter-number series, Picture completion, Block design, Matrices, Picture arrangement, Object assembly, Coding, and Symbol search.

Three IQ scores (Total IQ, Verbal IQ, Performance IQ), and four cognitive indexes (Verbal Comprehension, Perceptual Organisation, Working Memory, and Processing Speed) are computed after the WAIS-III subtests (see TEA, 1999; for details). Reliabilities (Split-half method) are shown in Table 1.

Table 1
Reliability coefficients in the total sample, and in every age group

SUBTEST	Total Sample	Age Groups (in years) 16-19	20-24	25-34	35-54	55-69	70-94
Vocabulary	.95	.87	.86	.90	.94	.95	.95
Similarities	.89	.81	.78	.83	.88	.88	.90
Arithmetic	.88	.80	.78	.84	.88	.87	.72
Digit span	.89	.86	.88	.89	.88	.86	.83
Information	.93	.90	.85	.88	.92	.92	.94
Comprehension	.85	.77	.77	.81	.82	.86	.89
Letter-number series	.95	.78	.81	.83	.86	.89	.80
Picture completion	.91	.72	.76	.78	.82	.89	.92
Coding(a)	–	–	–	–	–	–	–
Block design	.94	.83	.84	.90	.90	.92	.90
Matrices	.94	.76	.86	.85	.91	.94	.88
Picture arrangement	.86	.69	.71	.70	.81	.87	.81
Symbol Search(a)	–	–	–	–	–	–	–
Object assembly	.68	.50	.63	.50	.51	.59	.52

(a) Reliability coefficients were not computed for the Coding and Symbol search subtests in the Spanish standardization of the WAIS-III

Procedure

Analyses were performed through the Amos 3.6 statistical package (Arbuckle, 1997). Variances-covariances matrices were used as input data. Parameters were estimated by the Maximum Likelihood method.

Structural models

Five structural models were evaluated (figure 1): One-factor, oblique two-factor, oblique three-factor, oblique four-factor, and a model with a second-order factor.

The one-factor model supposes that only the *g* factor (Jensen, 1980, 1998) accounts for by the differences on performance on the WAIS-III subtests. Following this model, Total IQ would be the only reliable WAIS-III score. The oblique 2-factor model maintains the classical division between verbal and performance subtests. This model supposes that has sense to compute the Verbal and Performance IQs separately.

A third factor (commonly called Freedom from distractibility) has been identified in previous versions of the Wechsler scales. «Digit span», «Arithmetic», and «Coding» subtests have traditionally loaded on this factor. In the WAIS-III, two new subtest theoretically linked with them have been developed («Letter-number series» and «Symbol search»). These new subtests would reinforce this third factor, named «Attention». So, this model contains three factors: Verbal, Perceptual Organisation, and Attention.

According to the authors, the WAIS-III is intended to incorporate the advances on cognitive psychology. These efforts are directed to improve the assessment of the working memory.

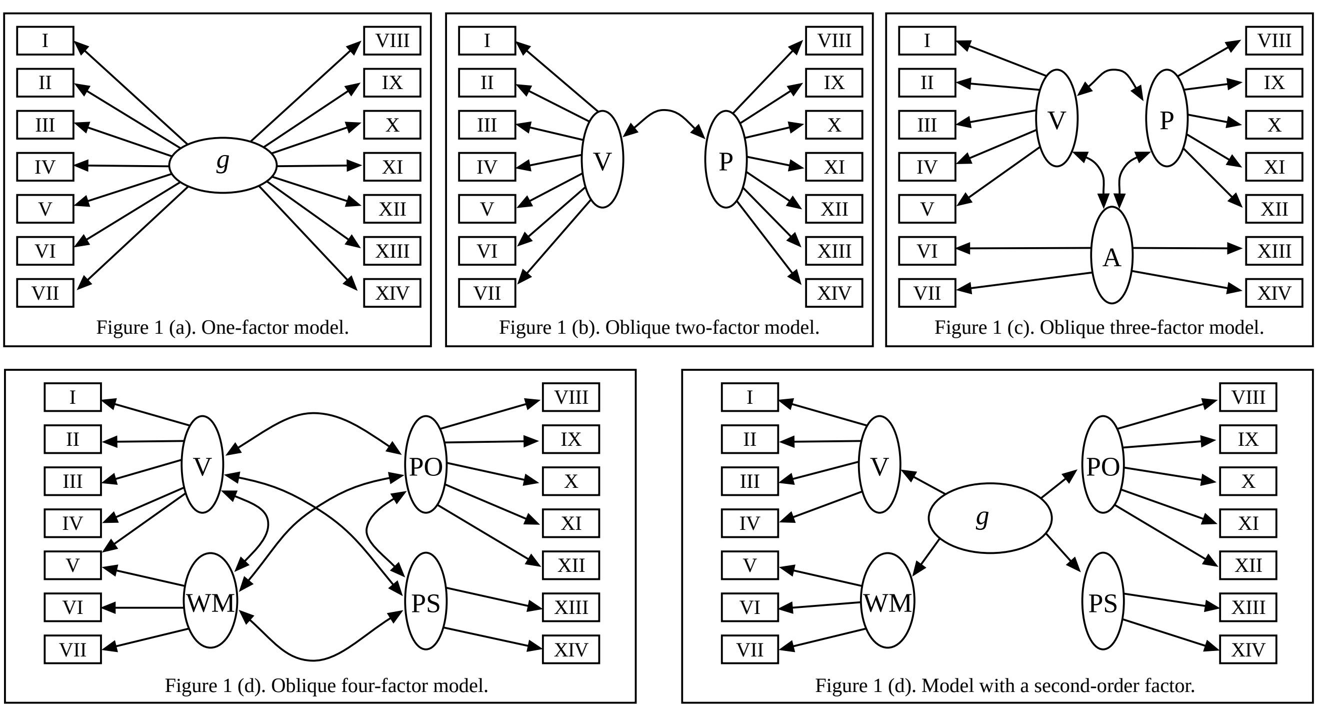

Figure 1 (a). One-factor model.
Figure 1 (b). Oblique two-factor model.
Figure 1 (c). Oblique three-factor model.
Figure 1 (d). Oblique four-factor model.
Figure 1 (d). Model with a second-order factor.

Figure 1. *Structural models [SUBTESTS: Vocabulary (I), Similarities (II), Information (III), Comprehension (IV), Arithmetic (V), Digit span (VI), Letter-number series (VII), Picture completion (VIII), Block design (IX), Matrices (X), Picture arrangement (XI), Object assembly (XII), Coding (XIII), and Symbol search (XIV). FACTORS: g= g Factor; V= Verbal; P= Performance; A= Attention; PO= Perceptual Organization; WM= Working Memory; and PS= Processing Speed]*

This construct has been presented as the main candidate to explain the differences in the *g* factor from a cognitive perspective (Colom, 1998; Kyllonen & Christal, 1990; Carpenter, Just, & Shell, 1990). On the other hand, a fourth factor, called Processing Speed, is extracted on the grounds of the strong relationship between the «Coding» and «Symbol search» subtests. So, this model contains four first-order factors: Verbal, Perceptual Organisation, Working Memory, and Processing Speed.

In all models, factors are hypothesised to be oblique since in previous exploratory factor analysis factor correlations ranged between .644 and .778 (extraction through the Principal Factors method with Promax rotation). The *g* factor is based on this positive manifold (Spearman, 1923; 1927; Jensen, 1998). *g* is currently located at the highest order of the structure of cognitive abilities (Carroll, 1993; Colom & Andres-Pueyo, 1999). Therefore, *g* could be extracted as a second-order factor in the WAIS-III. So, a fifth model adds one second-order factor to the oblique four-factor model as is shown in figure 1 (e).

Regression coefficients of the errors over the subtests (and over the first-order factors in the model with a second-order factor) were fixed to 1. Moreover, one loading on every factor was also fixed to 1 as follows (linked factors are in parenthesis):

- One-factor model: Matrices (*g*).
- Oblique two-factor: Vocabulary (Verbal), and Block design (Performance).

Table 2
Fit indexes in the total sample[a]

Model	χ^{2} [b]	d.f.	χ^2/d.f.	GFI	AGFI	NFI	TLI	CFI	RMSEA	AIC
One-factor	1926.86	77	25.024	.8	.727	.884	.868	.888	.133	1982.860
Oblique two-factor	1310.08	76	17.238	.861	.808	.921	.911	.926	.109	1368.088
Oblique three-factor	960.594	74	12.981	.903	.862	.942	.934	.947	.094	1022.599
Oblique four-factor	513.225	71	7.229	.950	.926	.969	.966	.973	.067	581.225
Second-order	567.343	73	7.772	.946	.922	.966	.963	.970	.070	631.343

(a) d.f.: Degrees of freedom. GFI: Goodness of Fit Index. AGFI: Adjusted Goodness of Fit Index. NFI: Normed Fit Index. TLI: Tucker-Lewis coefficient. CFI: Comparative Fit Index. RMSEA: Root Mean Square Error of Approximation. AIC: Akaike information criterion.
(b) All associated p were lower than .0001.

Table 3
Standardized factor loadings and factor correlations obtained in the total sample

STANDARDIZED FACTOR LOADINGS

SUBTEST	One-factor Factor	One-factor Loading	Oblique 2-factor Factor	Oblique 2-factor Loading	Oblique 3-factor Factor	Oblique 3-factor Loading	Oblique 4-factor Factor	Oblique 4-factor Loading	Second-order Factor	Second-order Loading
Vocabulary	*g*	.794	V	.841	V	.871	V	.881	V	.884
Similarities	*g*	.786	V	.826	V	.849	V	.857	V	.857
Information	*g*	.767	V	.812	V	.830	V	.823	V	.820
Comprehension	*g*	.712	V	.772	V	.802	V	.813	V	.813
Arithmetic	*g*	.769	V	.783	V	.756	WM	.784	WM	.782
Digit span	*g*	.730	V	.740	A	.755	WM	.813	WM	.814
Letter-number series	*g*	.819	V	.814	A	.850	WM	.897	WM	.899
Picture completion	*g*	.793	P	.800	PO	.803	PO	.803	PO	.802
Block design	*g*	.827	P	.849	PO	.854	PO	.854	PO	.854
Matrices	*g*	.878	P	.892	PO	.895	PO	.896	PO	.896
Picture arrangement	*g*	.827	P	.838	PO	.842	PO	.842	PO	.841
Object assembly	*g*	.773	P	.797	PO	.800	PO	.801	PO	.800
Coding	*g*	.798	P	.813	A	.846	PS	.884	PS	.886
Symbol search	*g*	.799	P	.819	A	.841	PS	.888	PS	.887

FACTORS CORRELATIONS, AND LOADINGS ON *g* IN THE MODEL WITH A SECOND ORDER FACTOR

STRUCTURAL MODELS

Oblique two-factor	P	Oblique three-factor	V	PO	Oblique four-factor	V	PO	WM	Second-order	Loading
V	.898	PO	.863		PO	.841			V	.864
		A	.836	.924	WM	.824	.871		PO	.968
					PS	.742	.893	.837	WM	.913
									PS	.909

– Oblique three-factor: Vocabulary (Verbal), Block design (Perceptual Organisation), and Coding (Attention).
– Oblique four-factor, and the model with a second-order factor: Vocabulary (Verbal), Block design (Perceptual Organisation), Digit span (Working Memory), and Coding (Processing Speed).

Finally, the *g* variance was fixed to 1 in the model with a second-order factor.

Results

Total sample (N = 1369)

Fit indexes obtained in the total sample appear in Table 2. χ^2 differences are always significant (α= 0.05). Looking at other fit indexes only models with four first-order factors show an acceptable fit. On the contrary, the one-factor, oblique two-factor, and oblique three-factor models do not fit well.

Table 4
Fit indexes in every age group[(a)]

Model	$\chi^{2\,(b)}$	d.f.	χ^2/d.f.	GFI	AGFI	NFI	TLI	CFI	RMSEA	AIC
16-19										
One-factor	210.133	77	2.729	.845	.789	.752	.792	.824	.103	266.133
Oblique two-factor	179.605	76	2.363	.872	.818	.788	.836	.863	.092	237.605
Oblique three-factor	160.846	74	2.174	.877	.818	.81	.859	.885	.085	222.846
Oblique four-factor	119.919	71	1.689	.903	.857	.858	.917	.935	.065	187.919
Second-order	120.564	73	1.652	.903	.860	.857	.921	.937	.063	184.564
20-24										
One-factor	206.742	77	2.685	.824	.76	.784	.823	.850	.105	262.742
Oblique two-factor	167.004	76	2.197	.861	.808	.825	.874	.895	.089	225.004
Oblique three-factor	121.846	74	1.647	.899	.857	.873	.932	.945	.065	183.846
Oblique four-factor	102.056	71	1.437	.917	.877	.893	.954	.964	.054	170.056
Second-order	106.330	73	1.457	.912	.874	.889	.952	.962	.055	170.330
25-34										
One-factor	369.138	77	4.794	.826	.763	.792	.794	.826	.118	425.138
Oblique two-factor	304.081	76	4.001	.858	.803	.828	.837	.864	.105	362.081
Oblique three-factor	252.990	74	3.409	.874	.821	.858	.869	.894	.094	314.290
Oblique four-factor	198.807	71	2.8	.901	.854	.888	.902	.924	.082	266.807
Second-order	201.684	73	2.763	.9	.856	.886	.905	.923	.081	265.684
35-54										
One-factor	687.472	77	8.928	.776	.695	.808	.793	.825	.14	743.472
Oblique two-factor	511.261	76	6.727	.828	.762	.857	.851	.875	.119	569.261
Oblique three-factor	394.975	74	5.337	.869	.814	.89	.887	.908	.103	456.971
Oblique four-factor	237.169	71	3.340	.923	.887	.934	.939	.952	.076	305.169
Second-order	251.669	73	3.448	.919	.883	.93	.936	.949	.078	315.669
55-69										
One-factor	376.074	77	4.884	.796	.722	.847	.851	.874	.128	432.074
Oblique two-factor	255.716	76	3.365	.862	.809	.896	.909	.924	.1	313.716
Oblique three-factor	252.271	74	3.409	.873	.820	.897	.907	.925	.101	314.271
Oblique four-factor	183.369	71	2.583	.904	.858	.925	.939	.953	.082	251.369
Second-order	203.357	73	2.786	.898	.854	.917	.931	.945	.087	267.357
70-94										
One-factor	224.029	77	2.909	.778	.698	.818	.848	.871	.119	280.029
Oblique two-factor	182.091	76	2.396	.828	.763	.852	.889	.907	.102	240.091
Oblique three-factor	151.866	74	2.052	.873	.82	.877	.916	.932	.088	213.866
Oblique four-factor	119.199	71	1.679	.896	.846	.903	.946	.958	.071	187.199
Second-order	123.472	73	1.691	.889	.841	.9	.945	.956	.072	187.472

(a) d.f.: Degrees of freedom. GFI: Goodness of Fit Index. AGFI: Adjusted Goodness of Fit Index. NFI: Normed Fit Index. TLI: Tucker-Lewis coefficient. CFI: Comparative Fit Index. RMSEA: Root Mean Square Error of Approximation. AIC: Akaike information criterion.
(b) All associated p were lower than .0001, except the Oblique four-factor and Second-order factor models in the 20-24 age group (p>.01)

Table 3 shows the standardised factor loadings obtained in the total sample. Factor loadings are high in all models, even in the one-factor model. Moreover, factor correlations, and the loadings on the *g* factor in the model with a second-order factor are also large. This fact would support that the *g* factor is the main cognitive ability assessed by the WAIS-III. However, the better fit of the oblique four-factor model suggests that other cognitive abilities also play a significant role.

Age groups

Fit indexes obtained by the five models in every age group are shown in table 4. Again, the oblique four-factor model obtains the best fit in all age groups. Besides, the one-factor, oblique two and, three-factor models do not reach acceptable values in any age group. However, compared to the four-factor model, there are no significant differences in the RMSEA (α = 0.1) in any age group when a second-order factor is added. Moreover, such model also gets a good fit in all age groups. Regarding the standardised solutions, results obtained in every age group reproduce the pattern presented in table 3.

Discussion

The model with the best fit was always the oblique four-factor model. This model obtains the lowest values in the χ^2 test as well as in the AIC. Moreover, other fit indexes (RMSEA, GFI, NFI, and CFI) present acceptable values. Results are congruent with those reported for the American (Randolph & Thompson, 2000), and Canadian samples (Saklofske, Hildebrand, & Gorsuch, 2000), where the oblique 4-factor model always reached the best fit. On the other hand, the models with one, two, and three factors, not only have a worse χ^2, but also the remaining fit indexes get unacceptable values. For instance, the RMSEA is always higher than .1 (Browne & Cudeck, 1993).

We would like to remark that fit indexes are very similar in both models with four first-order factors. Therefore, extracting a second-order factor is supported. It could be identified with the *g* factor (Carroll, 1993, Jensen, 1998; Juan-Espinosa, 1997), and would be the main cognitive ability assessed by the WAIS-III attending at the loadings on every structural model and the factor correlations. In this way, in a Schmid-Leiman hierarchical factor analysis conducted over the total sample (performed through Principal factors with Promax rotation procedure), the *g* factor accounted for by the 58.193% of the variance, whilst the four group factors altogether accounted for by the 14.107% of the variance only. Moreover, such percentages of variances are replicated in all age groups (Juan-Espinosa, García, Escorial, Rebollo, Colom, Abad, in press). Nevertheless, the bad fit of the one-factor model reinforces the current view about the hierarchical nature of the structure of cognitive abilities (Carroll, 1993). Finally, note that factor correlations get large values irrespective of the factor procedure (EFA Vs CFA) used.

Regard to the scores computed after the subtests of the WAIS-III, Total IQ as an estimation of the *g* level, and the four cognitive indexes as measures of lower-order factors report us useful psychometric information. However, several considerations must be done. Total IQ is computed through the simple summation of tests scores, so it is contaminated by other factors plus test's specificity, reducing their reliability as an individual's level estimation of the *g* factor (Colom, Abad, García, Juan-Espinosa, submitted; Escorial, Rebollo, García, Colom, Abad, & Juan-Espinosa). A similar critic can be risen regarding the four cognitive indexes. Note that loadings on the *g* factor are larger than those on the lower-order factors, so the cognitive indexes are also strongly contaminated by *g*. Besides, the processing speed index should be interpreted carefully since the reliabilities of the related tests are unknown in the Spanish population. Studies about those indexes should be carrying out to test if they improve the criterion validity of the Total IQ. Finally, Verbal and Performance IQs do not seem to make sense since the oblique two-factor model does not fit well to empirical data.

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