Cognitive screening for young children: Development and diversity in learning contexts

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Abstract

SYSTEMS [1] is a screen of general cognitive functioning, for school age children that entails cognitive manipulation and information skills. Our aim was to extend the test for four and five year old children at pre-school, to estimate theoretical starting points in typical cognitive profiles, that are critical in the early years. Participants (N = 1164, girls/boys, 50%) were four to 11 years old (mean 7.9, sd 2.2) at pre-schools and schools in diverse socio-economic areas of Sydney. Children's responses created the normative database, and the parameters were derived from curve estimation and regression procedures. Results suggest that cognitive screening is reliable and valid for younger and older children, and show a non-linear relation of children's test scores with age, that is characteristic of rapid change for younger children. The characteristic curve with the best fit to the data had a theoretical starting point before school age, at around 3 years of age. Findings are discussed in light of alternative models, and the clinical and educational applications.

Cognitive screening has an important role in clinical and educational practice.[2 3 4] Cognitive screening is conceptualised within the rapid development and diversity of cognitive functioning for children.[5 6] This project extended the SYSTEMS cognitive screening test for school age children[1] to younger children. The aim was to derive a model for typical profiles of children's general cognitive functioning. For young children particularly, it is important that screening for individual children is set against clear understanding of the characteristic non-linear profiles that underpin complex and rapidly changing cognitive, physical and social systems of development. The project outcomes necessarily rely on reliable indicators of cognitive functioning that can be extended to younger children.

Background to the project

The SYSTEMS cognitive screening test[1] was developed for school age children. Initially, the MMSE for adults[8] was expanded considerably for children who are assessed in clinical practice[7]. In 1999, SYSTEMS[1] was designed to screen cognitive functioning, with cut-off scores to suggest cognitive impairment, where full cognitive assessments are advisable. It is a general screening for clinical and research use, that entails children's cognitive manipulation and information skills. The content covers orientation, attention, concentration, memory and language. Research in clinical and educational settings show that the screening test is reliable over time, children's general cognitive functioning is stable over time, scores are sensitive to cognitive impairment, and scores show with strong correlations with full cognitive assessments[1 9 10].

A screening test for pre-school children

Children are referred to paediatricians, neurologists, psychologists and school counsellors for a range of cognitive and learning problems. Children may need evaluation for learning difficulties, present with symptoms such as persistent headaches, or sudden changes in behaviour. It is generally accepted that cognitive assessments are a routine part of a complete examination for any child presenting with such problems. However, cognitive development is more rapid and more diverse for younger children. This makes reliable indicators of cognitive functioning particularly important at this age. For instance, Billard and colleagues[2] demonstrate effective cognitive screening, and Scott, Fletcher, Jean-Francois, Urbano and Sanchez[11] provide eight tasks to identify children's learning problems. These tasks are useful in classifying young children with and without mild learning problems (although scores tended to be higher for girls than boys). Lenkarski and colleagues[4] also show that screening tests were useful in identifying pre-school children who are at risk for cognitive delays.

The SYSTEMS cognitive screening test was designed for five to twelve year old, school age children.[1] Typical profiles of test scores across age groups show characteristic non-linear relations of cognitive development. Typical profiles suggest more rapid cognitive development for younger children. This provided a sound base to extend general cognitive screening to pre-school children. This extension is critical for clinical and educational settings, and raised three important issues about screening tests for young children.

The first issue concerns reliability of the screening test for younger children. Outcomes indicate the generalisability of materials from school age children, for whom it was designed, to younger children of pre-school age. However, the early years present a challenging situation, considering the diversity of developmental profiles for younger children. In addition, Stipek and colleagues[12] suggest that pre-schools may be more diverse social and educational learning contexts. It was therefore plausible that formal assessment situations may have diverse meanings for younger children. However, the effectiveness of SYSTEMS cognitive screening with five-year old school children suggested that the materials would also be reliable with younger children at pre-school.

The second issue concerns the social context. It is important that the screening test scores are satisfactory, for younger girls and boys, in diverse locations. In principle, usefulness of a screening test may be limited where indicators of cognitive functioning are diverse among social contexts. Based on previous findings with older children[1], it was expected that cognitive screening would also create satisfactory unbiased indicators for younger children.

The third main issue concerns the profile of cognitive screening scores with age. It is important that test scores for individuals are considered in light of the theoretical distribution of cognitive scores with age. The project extended screening to younger children, to model typical profiles of cognitive scores, that is critical in the early years. Non-linear relation of children's test scores with age is characteristic of rapid change for younger children. Test scores were described by the curve: $y = a\,(1 - e^{-b.age})$,

where y is test score, a is the maximum, and the b coefficient characterises the curvature.

The key question is what theoretical starting point for age provides the best fit for typical profiles. There are at least three possibilities addressed empirically: (a) a general biological model would suggest typical profiles that pass through the origin, where age and test scores theoretically start at or about zero; (b) in socio-ecological models of development, starting points may be at the age of five years, with start of formal schooling, or (c) at a younger age, prior to formal schooling.

METHOD

Participants

Participants (N = 1164, girls/boys, 50%) were from 4.0 to 11.9 years of age. The locations were selected from diverse socio-economic suburban areas of Sydney (low 24%, medium 37%, high 29%). Sampling was based on age, gender and socio-economic indicators for areas (SEIFA, IEO).[13] Table 1 shows the distributions by age and gender. It is usual that some five- to five and a half years old children are in pre-schools and that some have already started school.

Table 1. - Distribution of participants by age and gender and location

location	gender	age 4	5	6	7	8	9	10	11 years
pre-school	girls	39	35						
	boys	45	32						
school	girls		76	83	76	76	63	67	69
	boys		72	81	75	70	68	73	64
Total		84	148	164	151	146	131	140	133

Materials

The SYSTEMS cognitive screening test[1] has 46 items on themes of orientation, registration, attention, calculation, recall, language, repetition, commands, reading, writing and copying. The responses are scored (1) correct or (0) incorrect, and sum to create the test score.

Procedure

The project was approved by the University Ethics Committee and the Children's Hospital at Westmead. Locations were randomly selection from low, medium and high areas of Sydney to represent Australian children by age and gender across socio-economic areas.[13] Schools and pre-schools in these areas were invited to participate. Children completed the cognitive screening test items with parental approval.

Analysis

Analysis used SPSS for descriptive (mean, standard deviation, range) and inferential statistics (correlations, analysis of variance, regression and curve estimation). Effect size of 0.5 sd and correlations $r \geq 0.30$ are considered meaningful.[14 15]

RESULTS

A reliable screening test for young children

The results suggested that the SYSTEMS cognitive screening test is also reliable, in terms of internal consistency, for four and five year old children in pre-school settings. Pre-school children's responses formed a reliable scale of general cognitive functioning, in terms of internal consistency (alpha = 0.82), and the screening test is also reliable for five to twelve year old children[1] (alpha coefficients above 0.70). In addition, the results show that cognitive screening test scores were unbiased by gender (F = 0.40, ns) and socio-economic indicators (r = 0.03, ns). Responses were therefore combined to create the normative database.

A model for children's cognitive screening by age

The distribution of children's test scores with age is described by the non-linear relation that is characteristic of rapid change for younger children. Test scores were described by the curve:

$$y = a\,(1 - e^{-b.age})$$

where y is test score, a is the maximum, and the b coefficient characterises the curvature.

The first step used regression analysis to find the best fit of the proposed model to data, in terms of R^2, and estimated parameter b, using the following transformation of the original equation:

$$-bx = \ln(1 - y/a)$$

where x is age, y is the test score, and a is the theoretical maximum score.

Curve estimation procedures used a theoretical maximum test score of just above the maximum possible score (a = 46.1). Although higher values may be of theoretical interest, higher values of *a* tended to increase the non-linearity at the extremes; that is, for both younger and older children.

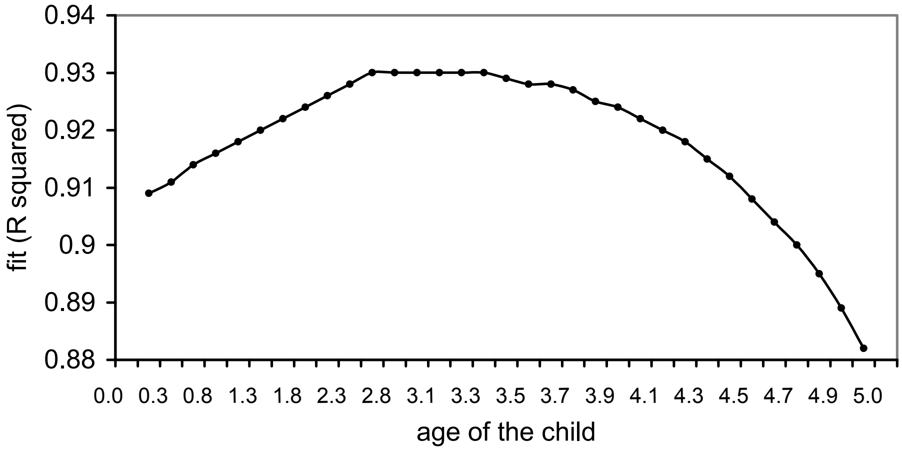

Figure 1. - Estimated fit of curve definition to the data with starting points between zero and five years old

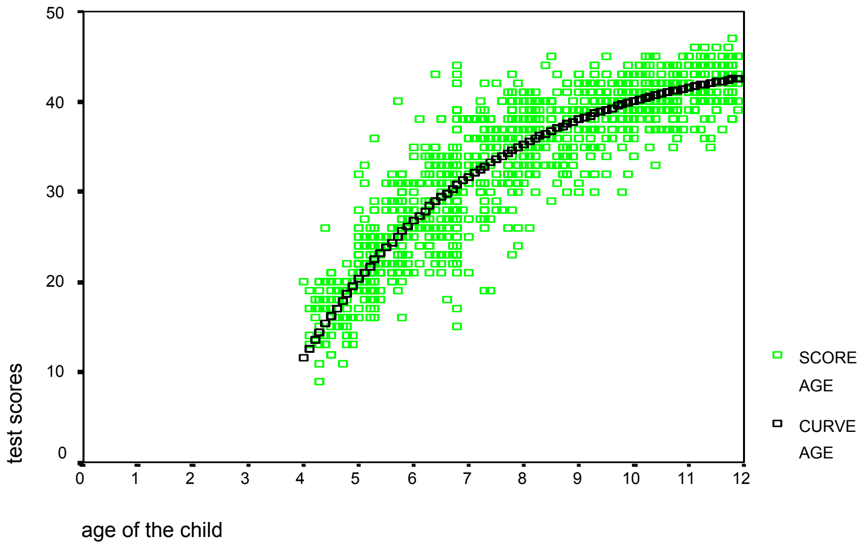

Figure 2. - Children's cognitive screening test scores for 4 to 12 year old children, and the characteristic curve fitted to the data.

Notes.

a. the characteristic curve for children's cognitive test scores is an asymptotic exponential function of age, $y = a\,(1 - e^{-b.age})$, with 3.0 as the starting point, b = -0.29 and a = 46.1.

Figure 1 shows variations in the fit of the model to the data. The starting point ranges from theoretical age zero to age five, for the exponential model of cognitive screening test scores. The results show a good fit of the model to the data for a theoretical starting points at age zero (R^2 explained 90% of the variance) and a theoretical starting point at age five (R^2 explained 88% of the variance). However, the results in Figure 1 show that the best fit of the model to the data (R^2 explained 93% of the variance) was for theoretical starting points for characteristic curves of test scores with age was in the range of two years and nine months to three years and three months. It was concluded that the best starting point for the theoretical characteristic curve for children's scores on the cognitive screening test was at or about three years of age.

The characteristic curve was then plotted for the database of children's responses. The value of b was estimated for three years of age (b = -0.296). Figure 2 is a scatter plot of children's cognitive screening test scores. It shows the theoretical distribution of test scores with age, using these estimates in the formula. (Raw scores were adjusted so that the 50th percentile was consistent with the predicted test score by age.)

Outcomes of the project are reported for children's responses to the test from a sound theoretical basis. Table 2 shows the means, standard deviations, with little variation in low skewness and kurtosis of children's test scores. The percentiles for the cognitive screening test were based on the best fit of characteristic curves of scores with age, for children's response to an internally consistent cognitive screening test. The percentiles of test scores for 4 to 11 year old children in Table 4, account for the effects of development in social context for five-year old children who are in pre-school and five-year old children who have started school.

Table 2. - Means and standard deviations for children's scores on the cognitive screening test by age

		age 4	5[a]	6	7	8	9	10	11 years
test scores	mean	16.5	23.0	29.4	33.4	36.4	38.9	40.8	42.1
	sd	3.0	3.9	5.2	4.6	3.2	3.2	2.5	2.4
	skewness	-0.32	0.79	0.32	-0.63	-0.11	0.64	-0.29	-0.60
	kurtosis	0.51	1.29	0.28	0.50	0.18	0.19	-0.22	-0.09

Note.

a. There was a moderate effect (0.6 sd) for cognitive screening test scores for 5.0 to 5.5 year old children, that were higher for children at school than pre-school ($t_{(140)} = 4.1$, $p<.001$).

Table 3. - Percentiles for children's cognitive screening test scores by age (*50th percentiles)

score	age 4	5[a]	5	6	7	8	9	10	11 years
46							100	100	100
45						100	99	99	96
44					100	99	99	89	82
43				100	99	99	96	79	64 *
42				99	99	98	89	65	47
41				98	97	96	76	52	38
40				98	95	91	65	36	25
39				97	91	84	55	21	13
38				95	88	75	44	14	8
37			100	92	77	61	34	5	5
36			99	91	70	51	20	3	2
35			99	90	57	40	14	1	1
34			99	87	53	27	8	1	
33			99	81	45	19	7	1	
32			98	74	36	12	7		
31		100	95	68	31	43	3		
30		99	91	60	20	3	2		
29		99	86	54	16	2	1		
28		99	86	47	15	1			
27		99	80	40	9	1			
26	100	99	73	30	6	1			
25	99	94	66	24	4				
24	99	88	53	18	3				
23	99	84	42	13	3				
22	99	78	32	8	2				
21	98	54	24	4	2				
20	94	6	12	3	1				
19	81	24	8	2	1				
18	64	10	4	2					
17	55	8	3	1					
16	38	3	1						
15	29	3							
14	23	2							
13	14	1							
12	7	1							
11	5								
<10	1								

Notes. a. Percentiles for five year old children who may be at pre-school or at school
b. scores at or below 25th percentile require full assessment, may indicate clinical impairment.

DISCUSSION

The results supported the proposal that the cognitive screening test with five to twelve year old school age children1 provides a sound base for a similar screening test for four and five year old pre-school children. Results suggest the screening test is also reliable for younger children. In practical terms, it therefore seems unnecessary to use a sub-set of items for younger children, with such a brief screening test. Results also show that the screening test is an unbiased indicator of cognitive functioning for younger and older girls and boys, across contexts.

The main issue concerned the distribution of children's test scores with age, that is critical for younger children. Children's cognitive development is characterised by rapid increases with age in indicators of general cognitive functioning, particularly for younger children. The results confirmed a good fit of the proposed exponential model to children's responses to the cognitive screening test. The key issue concerned the child's age that is the theoretical starting point for the model. The project tested three main possibilities that contrast a biological and a socio-ecological explanation in the context of schooling for profiles of children's cognitive test scores. A null model would suggest a biological explanation for age profiles. Typical profiles would pass through the origin (or earlier), where age and test scores theoretically start at zero. A socio-ecological model would suggest a good fit for the model with a starting point at age five years, the start of formal schooling. However, this would limit use of the screening test to school age children. The validity of the screening test as an indicator of general cognitive functioning, with both cognitive manipulation as well as information skills) suggests combined biological and social explanations. It is evident that the optimal alternative was found with the starting point for characteristic profiles of cognitive test scores with age that is prior to the start of school, at or around 3 years of age.

In summary, the findings show some support for general null model and social explanations of children's cognitive test profiles. However, the best explanation for characteristic profiles of children's cognitive screening test scores has a starting point at a younger age, around age three years, prior to formal schooling. In practical terms, this means the test is appropriate for younger children, and sampling strategies suggest the findings readily apply to four to twelve year old children at pre-schools and schools in Australia. We therefore conclude that cognitive screening extends to younger children, and suggest further research in clinical and educational settings.

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SYSTEMS cognitive screening test is available from Professor Robert Ouvrier at the Children's Hospital at

Westmead http://www.chw.edu.au/prof/services/neuro/systems.