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Regression-predicted age norms for the Children's Orientation and Amnesia Test

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Abstract

The Children's Orientation and Amnesia Test (COAT) was developed to assess posttraumatic amnesia (PTA) and cognitive functioning in children and adolescents who are in the early stages of recovery from traumatic brain injury. The COAT is composed of 16 items designed to assess general orientation, temporal orientation, and memory. The original norms are inadequate for several age groups because they were based on small sample sizes and may have been compromised by ceiling effects. In this study, normative data were collected for children between the ages of 8 and 13 ($N = 248$). Regression-predicted age norms were calculated and presented in tabular form. These results provide important reference data for interpreting COAT scores of children who have sustained traumatic brain injuries. © 2001 National Academy of Neuropsychology. Published by Elsevier Science Ltd.

Keywords: Posttraumatic amnesia; Traumatic brain injury; Children's Orientation and Amnesia Test

The duration of posttraumatic amnesia (PTA) is often used as a criterion for injury severity, and it is commonly believed to have prognostic significance for long-term outcome in persons who have sustained traumatic brain injuries. Indeed, the duration of PTA in children has been associated with later physical, neurological, cognitive, psychological, and educational functioning (Brown, Chadwick, Shaffer, Rutter, & Traub,

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1981; Chadwick, Rutter, Brown, Shaffer, & Traub, 1981; Ewing-Cobbs, Levin, Fletcher, Miner, & Eisenberg, 1990; Knights et al., 1991; Rutter, Chadwick, Shaffer, & Brown, 1980). Continued progress in understanding the relations between PTA and later functional status in children requires objective, reliable, and valid measures of PTA.

The Galveston Orientation and Amnesia Test (Levin, O'Donnell, & Grossman, 1979) has been used for 20 years as a standardized, objective measure of global orientation and duration of amnesia in adults who have sustained a brain injury. The Children's Orientation and Amnesia Test (COAT) was developed to assess recovery of cognitive functioning in children and adolescents (Ewing-Cobbs et al., 1990). The COAT is composed of 16 items designed to assess general orientation (e.g., name, parent's names, age, school, and grade), temporal orientation (e.g., year, month, and day of week), and memory (e.g., digits forward, Sesame Street character, and examiner's name; see Appendix A).

The original norms for the COAT are based on data obtained from 146 neurologically intact children between the ages of 3 and 15 (Ewing-Cobbs et al., 1990). The sample sizes for the individual ages ranged from 8 to 26 children. For children above age seven, the sample sizes in the original sample were quite small, ranging from 8 to 17. Such a limited normative base increases the likelihood of drawing inaccurate conclusions about an injured child's cognitive functioning relative to same-aged peers.

Moreover, the presence of a ceiling effect for the older children may artificially reduce the standard deviation for these age groups. For example, the maximum score on the COAT is 124, and the mean for the 12- to 15-year-old group in the original norms was 119.8 (Ewing-Cobbs et al., 1990). Even if the scores falling below the mean can be observed to display the full range of existing interindividual differences, the ceiling effect (which restricts the range of scores above the mean) would artificially reduce the resultant size of the standard deviation. This reduced standard deviation would then be used to test the extremity of scores that fall below the mean — the very scores that demonstrated more variability than was captured by the standard deviation.

This study provides additional normative information for children between the ages of 8 and 13. The normative method used provided regression-predicted percentile ranks. This technique allowed the tabular presentation of score distributions expected for a given age, thus preserving the natural distribution of scores. Moreover, this methodology necessitates the use of the entire sample to estimate the percentile ranks for a given age group, reducing the negative impact of dividing into smaller sample sizes. Finally, the impact of ceiling effects is reduced, because the standard deviation is not used to compute cutoff scores for impairment.

1. Method

1.1. Participants

Participants were 286 children from an elementary school in Columbia, MO. These children were part of a series of studies conducted by the third author. All children in the third through sixth grades in the school were eligible, and 94% returned informed consents. The subsample for this study was obtained by approaching each classroom and requesting that children leave for testing in alphabetical order. Some children in each grade were missed due to absence or experimenter time constraints. The children ranged in age from 8 to 13. In an effort to fill out the 8- and 13-year-old age groups, follow-up testing was conducted with children in second and eighth grades. Previous research demonstrated that children in special education perform more poorly on the COAT than children who are not receiving special services (Iverson, Iverson, & Barton, 1994). Therefore, those children known to be receiving special education services were excluded from the norms ($n = 38$).

Special education status was missing for 60 children. Post hoc significance tests (i.e., a one-way ANOVA followed by Tukey's HSD procedure for pairwise comparisons) demonstrated that the children with missing special education status did not differ significantly from the children in mainstream education on any of the COAT measures, but did differ significantly ($P < .01$) from the children receiving special services on temporal orientation, memory, and COAT total score. Therefore, the children with missing special education status were included in the normative sample.

The final normative sample contained 248 children. The sample included 127 males and 121 females. The breakdown of children by grade was as follows: (a) 18 in the second grade, (b) 48 in the third grade, (c) 41 in the fourth grade, (d) 40 in the fifth grade, (e) 65 in the sixth grade, and (f) 36 in the eighth grade. The breakdown of children by race was as follows: (a) Caucasian 125; (b) African-American 58; (c) Hispanic 1; (d) Asian 4; and (e) Indian (Asian) 1. Race was not coded for 59 children. The socioeconomic status of children enrolled at the school was lower middle to middle class, as estimated by the school principal (who used the number of free and reduced school lunches as part of the criteria for estimation).

There was no significant difference on the total score between males ($M = 117.31$) and females ($M = 117.04$), $t(246) = 0.39$, $P = .70$. Similarly, the mean total score did not differ between Caucasians ($M = 117.24$) and African-Americans ($M = 116.83$), $t(181) = 0049$, $P = .62$. However, there was a modest but statistically significant positive association between age and total score, $r(246) = .36$, $P < .001$. Therefore, the normative tables were adjusted for age.

1.2. Procedure

All children were individually administered the COAT according to standard instructions, within a 2-week period (see Appendix A). The test took approximately 5–10 min to administer. The examiner began each test by introducing herself with the phrase "My name is _____ (first name only). Can you remember that?" Throughout the test, if the child looked confused or responded in a manner that indicated a failure to understand the question, he or she was given a prompt. It was common for 8- and 9-year-olds to be confused on the questions regarding temporal orientation, especially day of the week and day of the month. For these questions, when younger children responded to "What day of the week is it?" with the day of the month, the examiner would say, "No, what day of the week is it? You know, like Saturday." (The authors of the original COAT study indicated that the temporal orientation questions could not be evaluated reliably in children under the age of eight, and thus these questions were not included in the calculation of total scores for young children in the original normative sample.)

Children's responses to the biographical questions were checked using their school cumulative records as a criterion. Children's responses regarding their parent's names were difficult to check because the cumulative school records contained the names of a "guardian" and a "spouse," but this information did not differentiate biological, step, and foster parents. Moreover, the records for many children did not even include a name in the "spouse" category. Thus, it was not possible to determine the accuracy of these responses. Therefore, all children were given full credit for this item, because we could not assume that a response that did not correspond with the school record was wrong. Notably, 97% of the children reported a parent's name that was listed in the school record as either "guardian" or "spouse." Only 3% of the sample provided an ambiguous response that was difficult to classify as a biological, step, or foster parent. Ambiguous responses were those in which only a guardian's name was listed, and this name did not correspond with the name provided by the child as either mother or father.

1.3. Normative method

The normative method used in this study provided regression-predicted percentile ranks. This technique allowed the tabular presentation of score distributions expected for a given age, while preserving the natural distribution of scores (i.e., the data were not force-normalized; Allen & Yen, 1979, pp. 163–164). The basic normative procedure consisted of five steps. First, each score was regressed on age using least-squares linear regression, and the unstandardized residuals were saved. Second, the resulting unstandardized beta coefficient for age, and the constant, were used to calculate predicted scores (Pedhazur, 1982, p. 17) for the age group in question (e.g., 10 years of age). Third, the scores that would comprise the distribution of scores for a given age were computed as the sum of (a) the predicted score for the age in question, and (b) the unstandardized residual scores saved from the aforementioned regression analysis. Fourth, the frequency distribution of the scores mentioned in step three was computed, yielding percentile ranks (also known as, regression-predicted percentile ranks) for the age in question. The final step was to assign *T* scores to the percentile ranks, in correspondence with the percentile ranks of the normal distribution (Odeh & Evans, 1974). This final step is entirely optional, and was carried out for the benefit of those clinicians who are more comfortable interpreting *T* scores than percentiles.

2. Results and discussion

Means, standard deviations, and ranges for the COAT subscale and total scores by age are presented in Table 1. The normative data for the COAT is presented in Tables 2–4. Age was a significant predictor of temporal orientation, memory, and COAT total

Table 1
Age-based means, standard deviations, and ranges for the COAT

		General orientation		Temporal orientation		Memory		Total score		
Age	*n*	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Range
8	30	39.8	0.7	36.5	4.8	35.1	5.4	112.5	7.0	98–124
9	41	40	0	37.8	2.7	38.8	4.6	116.6	5.4	102–124
10	46	40	0	38.3	2.1	38.2	5.1	116.3	6.0	102–124
11	41	40	0	38.4	2.4	39.8	4.1	118.2	4.6	108–124
12	50	40	0	38.6	2.0	39.7	3.6	118.3	4.1	105–124
13	40	40	0	39.1	1.9	40.8	1.5	119.8	2.4	110–124

The number of possible points was 40 for both general and temporal orientation, and 44 for memory.

score, $F(1,246) = 13.23$, $P < .001.$, $\eta^2 = 0.005$; $F(1,246) = 25.73$, $P < .001$. $\eta^2 = 0.10$; $F(1,246) = 35.68$, $P < .001.$, $\eta^2 = 0.13$, respectively. Therefore, predicted distributions for temporal orientation, memory, and COAT total score are presented for each age. As seen in Table 1, nearly all children obtained perfect scores on general orientation, so no normative data were provided for this score. This post hoc assignment of *T* scores to the total score predicted percentile ranks resulted in a near-normal distribution of *T* scores ($M = 50.1$, S.D. = 10.0).

Comparison of Tables 2–4 to the impairment criteria of the original norms (Ewing-Cobbs et al., 1990) illustrates the between-methodology disagreement on total-score cutoffs for

Table 2
Age-based percentiles and *T* scores for the temporal orientation subscale score

	Age											
	8 years		9 years		10 years		11 years		12 years		13 years	
Raw score	Percentile	*T* score	Percentile	*T* score	Percentile	*T* score	Percentile	*T* score	Percentile	*T* score	Percentile	*T* score
27	0.4	24	0.4	24	–	–	–	–	–	–	–	–
28	0.8	26	0.4	24	0.4	24	0.4	24	0.4	24	–	–
29	1	27	1	27	1	27	0.8	26	0.4	24	0.4	24
30	2	29	2	29	1	27	1	27	1	27	1	27
31	2	30	2	30	2	29	2	29	2	29	1	27
32	3	32	3	31	3	31	2	30	2	30	2	29
33	6	35	5	33	4	33	3	32	3	31	3	31
34	14	39	12	38	10	37	6	35	5	33	4	33
35	19	41	18	41	16	40	14	39	12	38	10	37
36	21	42	20	42	19	41	19	41	18	41	16	40
37	34	46	26	44	23	43	21	42	20	42	19	41
38	60	53	48	49	41	48	34	46	26	44	23	43
39	92	64	85	60	75	57	60	53	48	49	41	48
40	>99	–	>99	–	>99	–	>99	–	>99	–	>99	–

Table values represent the expected percentile for a given age group and the corresponding *T* score. Most percentiles and all *T* scores were rounded to a whole integer. A few percentiles are presented more precisely because rounding may lead to slight interpretational confusion.

Table 3
Age-based percentiles and *T* scores for the memory subscale score

	Age											
	8 years		9 years		10 years		11 years		12 years		13 years	
Raw score	Percentile	*T* score	Percentile	*T* score	Percentile	*T* score	Percentile	*T* score	Percentile	*T* score	Percentile	*T* score
24	0.4	24	–	–	–	–	–	–	–	–	–	–
25	0.4	24	0.4	24	–	–	–	–	–	–	–	–
26	1	27	0.4	24	0.4	24	–	–	–	–	–	–
27	4	33	2	29	0.4	24	0.4	24	–	–	–	–
28	9	37	5	33	3	31	0.4	24	0.4	24	0.4	24
29	13	38	9	37	5	34	3	31	0.4	24	0.4	24
30	15	40	13	38	10	37	7	35	3	31	1	27
31	16	40	15	40	13	38	11	38	9	37	4	33
32	16	40	16	40	15	40	14	39	12	38	9	37
33	17	40	16	40	16	40	15	40	15	40	13	38
34	17	41	17	40	16	40	16	40	15	40	15	40
35	21	42	17	41	17	40	16	40	16	40	16	40
36	34	46	24	43	18	41	17	41	17	40	16	40
37	44	48	35	46	28	44	21	42	17	41	17	40
38	60	53	46	49	40	47	32	45	21	42	17	41
39	74	56	61	53	48	50	42	48	32	45	21	42
40	84	60	76	57	65	54	54	51	43	48	34	46
41	95	66	87	61	78	58	68	55	57	52	44	48
42	99	73	97	68	88	62	80	58	70	55	60	53
43	>99	76	99	73	97	68	89	62	82	59	74	56
44	>99	–	>99	–	>99	–	>99	–	>99	–	>99	–

Table values represent the expected percentile for a given age group, and the corresponding *T* score. Most percentiles and all *T* scores were rounded to a whole integer. A few percentiles are presented more precisely because rounding may lead to slight interpretation confusion.

impairment. The original criterion for impairment was a score that was two standard deviations below the age-based mean. Thus, the cutoff scores from the original norms are as follows (the predicted percentiles from the present analysis that corresponds to each score are in brackets): age 8 = 103 (3rd percentile), age 9 = 98 (< 0.4th percentile), age 10 = 106 (4th percentile), age 11 = 108 (14th percentile), age 12 = 116 (22nd percentile), and age 12–15 = 116 (19th percentile).

In comparison, using the 2nd percentile score as a cutoff, the cutoff scores from the present analysis are as follows: age 8 = 102, age 9 = 103, age 10 = 104, age 11 = 105, age 12 = 106, and age 13 = 107. There are a number of explanations for these disagreements. First, it is likely that idiosyncrasies in the pattern of cutoff scores using the original method (e.g., the cutoff score for 9-year-olds is lower than the cutoff for 10-year-olds) can be attributed to small sample sizes (e.g., $n = 8$ for the group of 9-year-olds, and $n = 8$ for 12- to 15-year-olds), which may affect the accuracy of the means and/or the standard deviations. This issue is relatively minor for the present methodology, because the entire sample is used to estimate the cutoffs for each age group.

Table 4
Age-based percentiles and *T* scores for the COAT total score

	Age											
	8 years		9 years		10 years		11 years		12 years		13 years	
Raw score	Percentile	*T* score	Percentile	*T* score	Percentile	*T* score	Percentile	*T* score	Percentile	*T* score	Percentile	*T* score
100	0.4	24	–	–	–	–	–	–	–	–	–	–
101	1	27	0.4	24	–	–	–	–	–	–	–	–
102	2	30	1	27	0.4	24	–	–	–	–	–	–
103	3	31	2	30	1	27	0.4	24	–	–	–	–
104	4	33	3	31	2	30	1	27	0.4	24	–	–
105	7	35	4	33	3	31	2	30	1	27	0.4	24
106	8	36	7	35	4	33	3	31	2	30	1	27
107	10	37	8	36	7	35	4	33	3	31	2	30
108	14	39	10	37	8	36	7	35	3	32	3	31
109	15	40	14	39	10	37	8	36	5	34	3	32
110	17	40	15	40	14	39	10	37	7	35	5	34
111	20	42	17	40	15	40	14	39	10	37	7	35
112	23	43	20	42	17	40	15	40	14	39	10	37
113	29	45	23	43	20	42	17	40	15	40	14	39
114	38	47	29	45	23	43	20	42	17	40	15	40
115	51	50	38	47	29	45	23	43	19	41	17	40
116	58	52	51	50	38	47	29	45	22	42	19	41
117	66	54	58	52	51	50	38	47	24	43	22	42
118	76	57	66	54	58	52	51	50	33	45	24	43
119	85	61	76	57	66	54	58	52	46	49	33	45
120	91	63	85	61	76	57	66	54	56	51	46	49
121	96	68	91	63	85	61	76	57	62	53	56	51
122	98	70	96	68	91	63	85	61	73	56	62	53
123	99	74	98	70	96	68	91	63	82	59	73	56
124	>99	–	>99	–	>99	–	>99	–	>99	–	>99	–

Table values represent the expected percentile for a given age group, and the corresponding *T* score. Most percentiles and all *T* scores were rounded to a whole integer. A few percentiles are presented more precisely because rounding may lead to slight interpretation confusion.

Second, the tendency for small standard deviations to be associated with higher ages is probably due to a ceiling effect, whereby the variability is reduced because the mean score approaches the test maximum. This issue is also relatively minor using the present methodology, because the standard deviation is not used for computation of cutoff scores. Thus, assuming that the present set of norms are more accurate than the original set, the original cutoffs would appear to lack sensitivity for 9-year-olds, and result in too many false positives for children between the ages of 11 and 13. More appropriate cutoff scores may be the 2nd or 5th percentiles, as presented in Tables 2–4.

2.1. Correction for children receiving special education services

As reported previously by Iverson et al. (1994), the mean total score for children receiving special education services was significantly lower than a sample matched for age

Table 5
COAT means, standard deviations, and between-group significance test results pre- and postadjustment for special education status

		Preadjustment			Postadjustment[a]		
Score by group	*n*	Mean	S.D.	*t*	Mean	S.D.	*t*
Temporal orientation							
Regular education	37[b]	38.35	2.08	2.65**	38.35	2.08	0.82
Special education	37	36.51	3.67		38.51	3.67	
Memory							
Regular education	37	37.92	5.24	1.73	37.92	5.24	0.96
Special education	37	35.86	4.96		37.86	4.96	
Total score							
Regular education	37	116.00	6.12	2.41**	116.00	6.12	0.79
Special education	37	112.41[c]	6.69		116.41	6.69	

[a] Adjustment values used were 2, 2, and 4 points for temporal orientation, memory, and total score, respectively.

[b] The sample sizes reported in this table are one smaller than those listed by Iverson et al. (1994), due to the exclusion of an extreme score in the group receiving special education, and the corresponding age-, education-, and gender-matched counterpart in the regular education group. This child scored only 15 on temporal orientation, which altered the slope of the regression lines such that larger clinical corrections would have resulted.

[c] The mean reported in this table differs substantially from that reported in Iverson et al. (1994) due to a printing error in the latter publication.

** $P < .01$.

receiving regular education. Although conclusions reached by this study are limited by the small number of special services children sampled, the unstandardized regression coefficient for the special services grouping variable, assessed over and above the age variable, can be used to adjust the score of children receiving special services. This correction method allows use of Tables 2–4 for children receiving special education.

No correction was necessary for the general orientation subscale, because all children in special education obtained perfect scores on this measure. The beta weight for special education groupings was significant when predicting temporal orientation, memory, and COAT total score, $t(282) = 3.55$, $P < .001$; $t(282) = 3.28$, $P < .002$; $t(282) = 4.27$, $P < .001$, respectively. Therefore, the unstandardized β's were used as correction coefficients with which to increase the scores for children receiving special education services to allow use of the normative tables. These β's were 1.56, 2.49, and 3.97, respectively.

As a check of this correction method, a sample of children receiving regular education were age-, education-, and gender-matched to the group receiving special education (described in more detail by Iverson et al., 1994). In Table 5, it is demonstrated that preexisting differences between the matched groups are mitigated by the adjustment method. For clinical purposes, the adjustment values can be rounded to 2, 2, and 4 for temporal orientation, memory, and COAT total score, respectively. In other words, if a child is involved in special education, their temporal orientation, memory, and total scores should be adjusted upward by 2, 2, and 4 points before using the normative tables. Clinicians should consider these adjustments to be preliminary and experimental.[1]

2.2. Clinical use of the normative tables

As an example of how use of the original COAT impairment cutoffs may be misleading, refer to Slifer et al. (1996), who reported scores for four children with traumatic brain injuries. One 12-year-old child obtained a score of 109. As mentioned above, the accuracy of the mean (119.8) and standard deviation (1.5) reported for the 12- to 15-year-old group ($n = 8$) likely was affected by the small sample size and/or a ceiling effect. Using the original normative statistics, Slifer et al. (1996) concluded that this score was 7.2 standard deviations below the normative mean, for which the percentile value is too low to compute. On the assumption that the current normative tables are more accurate, by virtue of being relatively unaffected by the methodological problems mentioned above, this score falls at the 5th percentile, which is in the borderline classification range (*T* score equals 36).

Despite the potential advantages gained by use of this methodology, it is very important to consider these norms in perspective. They were based upon results obtained from midwestern school children who were tested while at school. These children are expected to be well oriented. A more appropriate comparison group for children who have sustained traumatic brain injuries would be hospitalized children with no neurological involvement. Some preliminary data on COAT performance in hospitalized children was presented by Baryza and Haley (1994). These were a few subjects ($n = 1-11$) from each age who were nonneurologically injured children. The mean scores for the children between 8 and 11 years of age all were in the average to high average range (i.e., the 58th–76th percentile), based on the current norms. Although these preliminary comparisons are encouraging, scores from a large sample of hospitalized children with no neurological involvement are necessary to ensure that the present normative tables are appropriate for use with children in acute recovery from a traumatic brain injury.

In summary, we have presented distributions of scores predicted for particular ages on the COAT total score, and two subscales (memory and temporal orientation), using data collected on 248 children. The means and standard deviations for the total scores were available in the original norms, and were based on very small sample sizes, and may have been influenced by a ceiling effect. Given that the present normative tables are relatively unaffected by these difficulties, they may provide substantial improvement over norms

[1] The adjustment in scores for children who are involved in special education is based on a small sample ($n = 37$), comprised of a disproportionate number of 9-year-olds (43%). The characteristics of this sample, which are different from the total sample, may reduce the stability/replicability of the obtained regression equations. In other words, the clinical correction values may change if these analyses were repeated with a large, age-heterogeneous sample of children in special education.

provided in the original study. Thus, these results provide important reference data for interpreting COAT scores of children between the ages of 8 and 13 who have sustained traumatic brain injuries.

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Appendix A. *Children's orientation and amnesia test (COAT)*

General orientation		
1. What is your name: first (2)		
last (3)		(5)
2. How old are you? (3)		
When is your birthday? Month (1)	Day (1)	(5)
3. Where do you live? City (3)		
State (2)		(5)
4. What is your father's name? (5)		
What is your mother's name? (5)		(10)
5. What school do you go to?(3)		
What grade are you in? (2)		(5)
6. Where are you now? (5)		(5)
(May rephrase question: Are you at home now? Are you in the hospital? If rephrased, child must correctly answer both questions to receive credit.)		
7. Is it daytime or nighttime? (5)		(5)
General orientation total		
Temporal orientation: (administer if age 8–15)		
8. What time is it now (5)		(5)
(correct = 5; < h off = 4; 1h off = 3;>1h off = 2; 2 h off = 1)		
9. What day of the week is it? (5)		(5)
(correct = 5; 1 off = 4; 2 off = 3; 3 off = 2; 4 off = 1)		
10. What day of the month is it? (5)		(5)
(correct = 5; 1 off = 4; 2 off = 3; 3 off = 2; 4 off = 1)		
11. What is the month? (10)		(10)
(correct = 10; 1 off = 7; 2 off = 4; 3 off = 1)		
12. What is the year? (15)		(15)
(correct = 15; 1 off = 10; 2 off = 5; 3 off = 1)		
Temporal orientation total		

Memory

13. Say these numbers after me in the same order.
(Discontinue when the child fails both series of digits at any length. Score 2 points if both digit series are correctly repeated; score 1 point if only 1 is correct.)

3	5	35296	81493	
58	42	539418	724856	
643	926	8129365	4739128	
7216	3279			(14)

14. How many fingers am I holding up? Two fingers (2)
three fingers (3) ________________ 10 fingers (5) (10)
15. Who is on Sesame Street? (10) (10)
(can substitute other major television show)
16. What is my name? (10) (10)

Memory total
OVERALL TOTAL

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