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# The impact of culture and education on non-verbal neuropsychological measurements: A critical review

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## Abstract

Clinical neuropsychology has frequently considered visuospatial and non-verbal tests to be culturally and educationally fair or at least fairer than verbal tests. This paper reviews the cross-cultural differences in performance on visuo-perceptual and visuo-constructional ability tasks and analyzes the impact of education and culture on non-verbal neuropsychological measurements. This paper compares: (1) non-verbal test performance among groups with different educational levels, and the same cultural background (inter-education intra-culture comparison); (2) the test performance among groups with the same educational level and different cultural backgrounds (intra-education inter-culture comparisons). Several studies have demonstrated a strong association between educational level and performance on common non-verbal neuropsychological tests. When neuropsychological test performance in different cultural groups is compared, significant differences are evident. Performance on non-verbal tests such as copying figures, drawing maps or listening to tones can be significantly influenced by the individual's culture. Arguments against the use of some current neuropsychological non-verbal instruments, procedures, and norms in the assessment of diverse educational and cultural groups are discussed and possible solutions to this problem are presented.

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## 1. Introduction

For almost a century of intelligence testing, efforts have been made to develop “culture free” tests (Jensen, 1980). Different attempts are found in the history of psychological testing to construct measures that would be “culture-free” (Anastasi, 1988; Cattell, 1940). For some time, it was supposed that the effect of culture could be controlled if verbal items were eliminated, and only non-verbal, performance items were used. However, this assumption turned out to be wrong. Researchers using a wide variety of cultural groups in many countries have sometimes observed even larger group differences in performance and other non-verbal tests than in verbal tests (Anastasi, 1988; Irvine & Berry, 1988; Vernon, 1969). Therefore, not only verbal, but also non-verbal tests may be culturally biased. The use

of pictorial representations itself may be unsuitable in cultures unaccustomed to representative drawings, and marked differences in the perception of pictures by individuals of different cultures have been reported (Miller, 1973). Furthermore, non-verbal tests often require specific strategies and cognitive styles characteristic of middle-class Western cultures (Cohen, 1969).

Regardless of the contrary evidence, the idea that non-verbal cognitive tests can be culturally free has significantly remained. Currently, there is a diversity of intellectual tests that are presented as “culture-free,” or “culture-fair” just because they include mostly non-verbal items (e.g., Alexander, 1987; Crampton & Jerabek, 2000). This point of view contradicts available anthropology and cross-cultural psychology evidence (e.g., Berry, Poortinga, & Segall, 1992; Harris, 1983; Irvine & Berry, 1988). Cole (1999), for example, has argued that the notion of culture-free intelligence is a contradiction in terms. He points out that cross-cultural test construction makes it clear that tests of ability are

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inevitably cultural devices, and hence a culture-free test is an illusion.

In clinical neuropsychology, it has often been considered that the use of non-verbal items ameliorates the impact of culture on testing. A significant portion of the assessments used in intercultural settings typically emphasizes non-verbal skills such as visual-spatial abilities (Boivin, Giordani, & Bornefeld, 1995). Furthermore, the performance of some non-verbal tasks such as drawing a map and copying figures are frequently considered in neuropsychological assessment to be universal skills of most normal adults (Lezak, 1995). In contrast, it has also been argued that drawing a map or copying figures represent abilities that are absent in many cultures (Ardila & Moreno, 2001; Berry et al., 1992; Irvine & Berry, 1988), and are highly school-dependent skills (Ardila, Rosselli, & Rosas, 1989).

Culture is understood as the way of living of a human group and includes behaviors, ways of thinking, feeling, knowledge, values, attitudes, and belief (Harris, 1983). Cultural elements (the physical elements characteristic of that human group such as symbolic elements, clothes, ornaments, houses, instruments, weapons, etc.) are also included in the definition of culture. Education can be regarded as an element of culture (Ardila, Ostrosky, & Mendoza, 2000) and includes literacy and schooling. Literacy refers to the acquisition of reading and schooling to the process of learning at school. Culture and formal education (as a cultural element) have significant effects on cognition (Berry, 1979; Cole, 1997). Greenfield stated “the major factor that makes a culture more or less different from the culture conventions surrounding ability testing is the degree of formal education possessed by the participants” (Greenfield, 1997, p. 1119). Culture prescribes what is learned and at what age (Ferguson, 1954; Irvine & Berry, 1988). Formal education is a most significant element in culture, even though formal education can be interpreted a kind of transnational culture. The fundamental aims of school are equivalent for all schools and school reinforces certain specific values regardless of where they are located. Hence, school could be seen as a culture unto itself, the culture of school. School not only teaches, but also helps in developing certain attitudes that will be useful for future new learnings (Ardila et al., 2000).

The question that this article raises is whether the use of non-verbal neuropsychology tests commonly used with American children and adults are appropriate for populations from diverse cultures and different educational levels. To approach this question, this paper analyzes the findings from different published studies of the influence of culture and schooling on non-verbal neuropsychological measurements. This paper will compare the following. (1) The performance in non-verbal test among groups with different educational levels and same cultural background (inter-education intra-culture

comparison). Studies in different cultures will be presented. (2) The performance among groups with the same educational level and different cultural backgrounds (intra-education inter-culture comparisons).

## 2. Different educational level, same cultural background

Education has an important influence on cognitive test performance. Groups with higher levels of education perform better on most neuropsychological tests (Ardila et al., 1989; Ostrosky, Ardila, & Rosselli, 1999; Rosselli, Ardila, & Rosas, 1990). This effect has been well documented in intelligence tests (Matarazzo, 1972) and in verbal neuropsychological tests (Acevedo et al., 2000; Reis & Castro-Caldas, 1997; Rosselli et al., 1990). The effect of education, however, has been less studied in non-verbal tests. This section analyzes the effects of schooling on non-verbal neuropsychological test performance in participants with diverse cultural backgrounds. Three examples will be used.

The effect of formal education on constructional ability test scores has been reported in healthy participants from different cultural groups. Unverzagt et al. (1996) describe significantly better copying of geometrical designs (using the designs from the Consortium to Establish a Registry for Alzheimer's Disease's Neuropsychological Battery: CERAD-NB; Morris et al., 1989) in African American elderly subjects with an average of 14.4 years of schooling when compared to an African American group with similar age but with an average of 7.1 years of schooling. Education was found to account for a significant percentage of the variance in test scores.

The influence of schooling and literacy on the Rey-Osterrieth Complex Figure (ROCF) scores has been described in two Western culture samples from Colombia (South American) with ages from 21 to 75 years (Ardila & Rosselli, 2003; Ardila et al., 1989; Rosselli & Ardila, 1991). The ROCF scores found in these studies are represented in Fig. 1. Scores increase with the educational level of the subjects. The authors found a gender effect that interacted with level of education. Males and females differed in their ROCF scores only in the lower educated groups. The difference between males and females is not significant in the highly educated groups.

An effect of education on non-verbal tests has also been reported in children. Klenberg, Korkman, and Lahti-Nuuttila (2001) using 440 Finnish children (age 3–12 years) found that parental education level had an effect on the development sequence of attention (i.e., visual search) and non-verbal executive function (i.e., design fluency) test scores. Education level was rated using three categories: lower level (4–9 years of primary school, secondary education or vocational school), medium level (senior high school or college), and higher level (university education). A main effect of education and significant

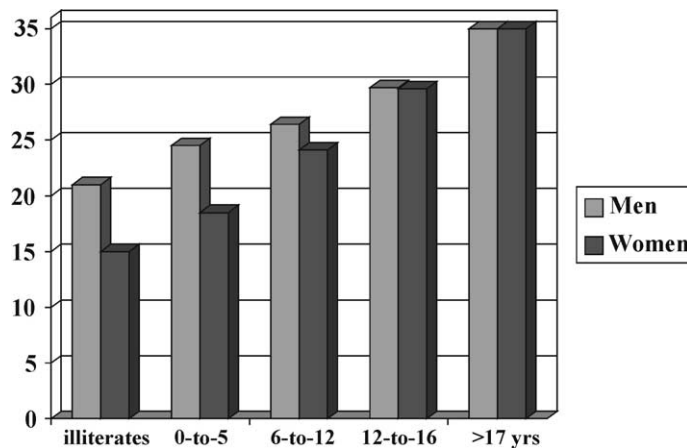


Fig. 1. Performance in the Rey-Osterrieth Complex Figure in normal subjects with different levels of education (age = 21–75 years;  $N = 824$ ) (Ardila & Rosselli, 2003; Ardila et al., 1989).

interactions between age and parents' education were found in the Design Fluency subtest but were not consistent in the Visual Search subtest. Medium and higher levels of education was related to higher performance in Design Fluency, and this effect was stronger in the older groups. The authors suggested that the development of non-verbal executive functions in children is more strongly connected to environmental variables and learning than is the early development of non-verbal attention.

It can be concluded when comparing individuals with different educational levels within the same cultural group (African Americans, Colombian, Finns) that a significant effect of educational level on non-verbal neuropsychological tests, is found in both adults as in children.

### 3. Same educational level, different cultural background

Culture can affect the development of non-verbal skills (for a review see Ardila & Keating, in press). Ecological demands and cultural practices are significantly related to the development of perceptual and cognitive skills (Cole & Means, 1986). Cross-cultural differences in perceptual and constructional abilities have been extensively studied in anthropology and cross-cultural psychology (e.g., Berry, 1971, 1979; Brislin, 1983; Gay & Cole, 1967; Hudson, 1960, 1962; Laboratory of Comparative Human Cognition, 1983; Segall, 1986). For instance, Hudson (1960, 1962) studied depth perception using pictures that contained figures of an elephant, an antelope, and a man with a spear; the basic question referred to what the man was doing with the spear. There were four pictures differing with respect to the cues available for the interpretation of the picture. This set of pictures was used with different groups of people from Africa and Europe. It was observed that European children around 7–8 years have a great diffi-

culty perceiving the picture as three-dimensional. However, around 12 years, virtually all perceived the picture as three-dimensional. Not so with Bantu or Guinean children. Non-literate Bantu and European laborers responded to the picture as flat, not three-dimensional. They were unable to interpret figures represented-on-a-paper-in-three-dimensions; this also holds true in general for illiterate people (Ardila et al., 1989). In general, people untrained to use maps cannot understand and cannot draw a map, even a simple map such as the map of the place where the subject is situated. Dawson (1967) suggests that general exposure to pictorial material might not be enough for learning pictorial representation and some use of pictorial material is also required.

People in non-western cultures who are not exposed to these non-verbal tests would be expected to perform differently from people in western cultures. Salmon, Jin, Zhang, Grant, and Yu (1995) found that Chinese elderly, both educated and uneducated, were unable or unwilling to perform written and drawing tasks. When Chinese participants have been compared to Finnish participants they perform poorer in the copying of designs but better in recalling words (Salmon et al., 1989). While writing and drawing with pen or pencil may be highly over-trained in the West, Chinese education may have placed less emphasis upon the acquisition of this skill.

Other researchers have also demonstrated the inappropriateness of using drawing tests in assessing members of non-western societies. Ardila and Moreno (2001) administered a neuropsychological battery to the Aruaco Amerindians of Colombia (South America). The battery included verbal and non-verbal tests. Among the non-verbal tests were the ROCF, the overlapped figures tests (specially designed for this study, and including objects taken the Aruacos' environment), and drawing a map test (the map of the room where testing was done). The authors divided the sample into two groups: the

older sample (age 15–30) and the younger sample (age 8–14). Both groups performed very poorly in copying figure tests and drawing a map. Because map drawing is a virtually non-existing task in Aruaco culture, it is likely that subjects did not understand what they were supposed to do. It is noteworthy, that subjects' performance was at ceiling on other non-verbal test—recognition of overlapped figures.

The Aruaco groups had a low level of education. In consequence, it may be difficult to distinguish the effect of culture from the effect of education on their test scores. In order to clarify the independent effect of the Amerindian culture on the ROCF test performance, the scores found in the Aruaco sample were compared to the scores of available data of two Colombian samples from Bogotá (western culture) (Ardila et al., 1989; Ardila & Rosselli, 1994, 2003) and one sample from Canada (Kolb & Whitshaw, 1990) with a similar education level (see Table 1). The Aruaco samples presented larger standard deviations than the Western samples in the copying conditions but not in the memory condition. The copying of the figure was very difficult for the Aruaco adult sample and easier for the younger Aruaco sample. The mean of the younger Aruaco sample was within one standard deviation of the mean of the western-Colombian samples, and within one standard deviation of the mean of the Canadian sample. This score difference between the older and the younger samples might be explained by the fact that all the participants in the younger sample had some formal education and thus perhaps more contact with Western culture. When education level was controlled, there was a difference in performance between participants from Aruaco and Western cultures. Drawing is not a culturally reinforced ability among Aruaco Indians.

Cultural differences independent of education effects emerge clearly when the ROCF memory scores from Table 1 are reviewed. Both the younger and the older Aruaco samples had similarly low levels of performance showing difficulties in remembering the details of the complex figure while the Canadian and western-Colombian samples had similarly high scores. The Arua-

cos' scores were more than two standard deviations below those scores found in the western samples. This suggests that although children of the non-western societies are trained to copy nonsense figures, it seems that the culture of the Aruaco does not reinforce the training for the recall of nonsense drawings and that therefore this is not a fair test to evaluate non-verbal memory. It is important to mention that the Aruaco groups performed very well in other non-verbal tests (e.g., recognizing superimposed figures) providing further evidence that the impact of culture may some times be even stronger in non-verbal than in verbal tests.

Significant differences in non-verbal test performance between western and non-western school children have been recently reported by Mulenga, Ahonen, and Aro (2001). They administered the NEPSY (Korkman, Kirk, & Kempt, 1998) to a small sample of Zambian children and compared their performance with the US norms. They found that Zambian children performed poorer in the domain of language, attention, and executive functions but better in visuospatial tests (design copying). Mulenga et al. make the interesting observation that, although there were clear instructions to perform the task as fast as possible, most children tended to work slowly. Other authors have confirmed this finding that members of many cultures are frequently slower in speed of performance when compared with US children. "Fast performance" is obviously an important culture value in the US, but it is absent in many other cultural groups. Zairian children for example, are slower in the Tactual Performance Test than the American and Canadian children (Boivin et al., 1995). Spanish children are slower in the Trail Making Test as compared with US children (León-Carrión, 1989). The fairness of timed tests in the assessment of cognitive abilities is challenged by these results. Or rather, there is a need for culture-specific norms in timed tests. Both speed and accuracy at performance are values in the US culture, which also emphasizes competitiveness and success.

Boivin et al. (1995) investigated the utility of the Tactual Performance Test for Zairian children from 5 to 12 years of age. The authors found that the Zairian

Table 1  
Performance of different cultural groups in the ROCF test

	Adults		Children		
	Colombian Aruacos (1)	Colombian Western (2)	Colombian Aruacos (3)	Colombian Western (4)	Canadian Western (5)
N	11	20	9	20	329
Age	21.8 ± 4.9	21–30	10.7 ± 2.1	9–10	9
Education	3.2 ± 2.4	0–5	3.0 ± 1.9	3.5	
Gender	8M/3F	9M/11F	4M/5F	10M/10F	
ROCF copy	13.7 ± 7.4	28.4 ± 3.8	20.8 ± 7.5	24.6 ± 4.7	24.4 ± 6.9
ROCF memory	6.6 ± 6.38	17.8 ± 5.0	6.3 ± 6.4	17.0 ± 6.3	18.7 ± 6.6

1 and 3—Ardila and Moreno (2001).

2 and 4—Ardila and Rosselli (1994).

5—Kolb and Whitshaw (1990).

children as a whole did not display an improvement between the preferred and non-preferred hand trials, as is characteristic for the US and Canadian children. For all ages, but particularly for the younger samples, it was very difficult for subjects to complete the task with the non-preferred hand. The authors interpret these results as more a consequence of a developmental lag than an enduring neuropsychological deficit. In this study, half of the Zairian children were considered at risk nutritionally and developmentally on the basis of anthropometric measures while the children from the US and Canadian sample were well nourished. Thus, the differences found in this sample are not necessarily all due to cultural differences but also other variables—such as public health problems, may be involved. In addition, as the authors noticed, the difference between the African children and the North American children could be due to differences in experience with the test items. While in the North American culture children have played with standard geometrical shapes at a very early age, many of the Zairian children could not name most of the shapes of the blocks. The authors suggested that although there is cultural limitations to the use of the TPT for Zairian children with the current North American norms, the test might have a potential neuropsychology application if African children are compared with their own reference group. Obviously, each individual has to be compared with his/her own group, sharing the same cultural values, experiences, and environmental conditions.

Perez-Arce and Puente (1996) caution that educational experience and educational level are frequently confounded with cultural factors. In the US, many of the Hispanic immigrants or the African American groups have low levels of education, and any differences with mainstream American individuals may be due to lack of schooling, rather to the effect of culture. Ardila (1995) has proposed a similar point of view. He points out that differences in test performance between “Anglos” and “Hispanics” (or other cultural or subcultural

groups) in the US, are easily attributed to cultural variables. But most often, differences are simply the result of differences in educational levels.

Differences in non-verbal test scores in children from two types of western societies have also been reported by Rosselli, Ardila, Bateman, and Guzmán (2001). They compared the performance of Colombian children (western, low industrialized society) with the American normative sample (western, industrialized society) on several verbal and non-verbal measurements. In most of the tests, the performance of the two cultural groups was similar. However, in the Seashore Rhythm test, the Colombian group performed significantly better, two standard deviations above the mean for American normative data reported by Findelieis and Weight and cited by Nussbaum and Bigler (1997) (see Table 2). It may be conjectured that musical learning represents a significant cultural value for Colombian children. Cultural differences in the Seashore Rhythm test have also been reported among the subcultures in the United States. African American males showed significant higher scores in the Seashore Rhythm test as compared to European Americans and Hispanics (Bernard, 1989; Evans, Miller, Byrd, & Heaton, 2000). The Seashore Rhythm test was originally developed to assess musical ability (Mitrushina, Boone, & D’Elia, 1999) but the perceptual skills this test requires may be shaped by cultural influences. Arnold, Montgomery, Castaneda, and Longoria (1994) documented a significant effect of acculturation on the Seashore Rhythm test in a group of Mexican Americans with better performance in those that were better acculturated. Cultural effects on the Seashore Rhythm test, likely associated with familiarity and relevance of tone discrimination task, have been reported (Klove, 1974).

Other studies have claimed similarities in the performance of constructional tasks in western and non-western samples. Osuji (1882) analyzed the ability of Nigerian children to construct geometric patterns and compared

Table 2

Performance of Colombian (Rosselli et al., 2001) and US children (Benton-Sivan, 1992; Nussbaum & Bigler, 1997) in some non-verbal tests

Test	6–7 years Mean $\pm$ SD	8–9 years Mean $\pm$ SD	10–11 years Mean $\pm$ SD
<i>Seashore Rhythm test</i>			
Rosselli et al. (2001) ( $n = 290$ )	21.65 $\pm$ 4.57	23.21 $\pm$ 4.05	24.72 $\pm$ 3.47
Nussbaum and Bigler (1997)	NA	14.23 $\pm$ 5.50	18.97 $\pm$ 6.30
<i>Finger tapping: Preferred hand</i>			
Rosselli et al. (2001) ( $n = 290$ )	32.25 $\pm$ 4.96	35.52 $\pm$ 5.35	41.08 $\pm$ 5.08
Nussbaum and Bigler (1997)	31.77 $\pm$ 3.95	35.20 $\pm$ 4.35	39.12 $\pm$ 5.10
<i>Finger tapping: Non-preferred hand</i>			
Rosselli et al. (2001) ( $n = 290$ )	28.16 $\pm$ 3.81	30.76 $\pm$ 4.65	35.48 $\pm$ 4.99
Nussbaum and Bigler (1997)	28.61 $\pm$ 3.45	31.17 $\pm$ 3.55	34.55 $\pm$ 4.80
<i>Benton visual retention (copy): Correct</i>			
Rosselli et al. (2001) ( $n = 290$ )	7.85 $\pm$ 2.18	8.73 $\pm$ 1.52	8.97 $\pm$ 0.98
Benton-Sivan (1992)	6.19 $\pm$ 2.28	7.22 $\pm$ 1.96	8.28 $\pm$ 1.32

their performance with that of Canadian children. The performance of both groups was very similar, although the Nigerian children tended to achieve the ability at a slightly younger age.

Frequently cultures that are dissimilar in cognitive scores from European Americans are considered “culturally deprived.” Few studies have attempted to understand these differences as the result of differences in cultures, and not just as the “lack” of the “modal western abilities.” It is understandable that the members of the test developer’s cultural group usually obtain the highest scores, simply because the test developer will select what he/she considers most relevant. For the dwellers of the Amazonian jungle the most culturally relevant ability may be to get oriented in the jungle, a complex ability very unlikely to be included in a neuropsychological test battery, unless the test battery were developed by an Amazonian jungle dweller.

Ardila et al. (2000) has pointed out that a significant misunderstanding may exist with regard to the education effects. Educated people do not necessarily possess abilities that less educated individuals are lacking. It does not mean that highly educated people have the same abilities that less educated individuals have, plus something else. Formal cognitive testing evaluates those abilities that the educated child was trained in, and is not surprising that he or she will outperform the child with no formal education. It must be emphasized that educational level has a substantial relationship with performance on some cognitive tests but is not systematically related to everyday problem solving (functional criterion of intelligence) (Cornelious & Caspi, 1987). It is not totally accurate to assume that people with low levels of education are somehow “deprived.” It may be more accurate to assume that they have developed different types of learnings. If tests were based on the knowledge and skills better developed by those with low levels of formal education, then highly educated people would be at a disadvantage.

#### 4. Conclusions

Great caution is needed in using non-verbal neuropsychological tests with individuals from cultures different from the one that provided the normative sample. The interpretation of the performance of individuals from other cultures using US norms might result in significant errors in assessment, particularly if the examiner’s intention is to evaluate the integrative of the brain–behavior relationship (Boivin et al., 1995).

Drawing a map and copying figures as measured by neuropsychological tests are not universal skills. They can be meaningless to members of some cultures. In addition, timed non-verbal tests that score speed of performance are influenced by the individual’s culture

and are unfair to use with people to whom time restrictions are not so important values within the culture. It is clear that not only verbal, but also non-verbal tests may be culturally biased. Reynolds (2000) suggests that the bias in neuropsychological tests should be corrected by using appropriate statistical methods. If no corrections are done to the current tests, then new tests should be developed for specific cultural groups because group differences in performance are artifacts of the tests and do not truly represent group differences in skill, ability or knowledge.

Non-verbal tests currently used in US neuropsychology are not necessarily more appropriate for cross-cultural testing than verbal tests. Ardila and Moreno (2001) found that the Aruaco Indians’ performance was particularly low in the ROCF and Draw-a-Map test, whereas their verbal fluency test performance was in the normal range. Conversely, Mulenga et al. (2001) found that the Zambian children performed better in visuospatial tests (design copying) than US children. Visuoconstructive and visuospatial test scores may be lower or higher in diverse cultural groups, but the important point is that they may be different.

Some non-verbal abilities may be surprisingly high in other cultural groups. Spatial orientation may be crucial for Amazonian Indians, and seemingly their ability to use some topographical marks and shapes is related with their lifelong experience to move around the jungle. Non-western people can do better or worse, depending upon the specific ability that is tested. As mentioned, performance scores in the Seashore Rhythm test for Colombian participants are almost twice those of US children; recognition of overlapped figures was virtually perfect in Aruaco Indians when using elements from their environment, etc.

There is a clear need for cross-cultural variability versus invariance studies that establish the degree of dependence of non-verbal functions on environmental influences (Korkman, 2001). In addition it is important to develop specific methods of assessment of non-verbal abilities based on the individual’s culture. Nell (2000), for example, developed methods of neuropsychological assessment for low educated South African patients. These methods include familiarization with the test procedures and intensive coaching.

In a recent article, Eviatar, 2000 argues that culture is a variable that like age or gender can be crucial in delimiting the manner in which higher cognitive processes are related to brain organization. According to Eviatar, attention habits developed as a result of reading direction can affect performance asymmetry for non-language tasks. Readers of right to left languages do not show the ubiquitous left preference in the chimeric faces task. According to Eviatar, this lack of bias should be interpreted as due to the effects of scanning habits rather than due to differential lateralization of visual abilities.

Other skills prescribed by a culture, together with the cognitive strategies that vary among human cultures, interact with inherent patterns of brain organization. It is very likely then that many of the differences found in non-verbal cognitive test scores in dissimilar cultural groups are the result of a complex interaction of brain organization and culture experience and learning (Ardila, 2003).

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## References

- Acevedo, A., Loewenstein, D. A., Barker, W. W., Harwood, D. G., Luis, C., Bravo, M., Huewitz, D. A., Aguero, H., Greenfield, L., & Duara, R. (2000). Category fluency test: Normative data for English and Spanish speaking elderly. *Journal of the International Neuropsychological Society*, 6, 760–769.
- Alexander, W. P. (1987). *Apresiasi de la inteligencia práctica y libre de influencia cultural [Appraisal of practical and culture-free intelligence]*. Madrid: Tea Ediciones.
- Anastasi, A. (1988). *Psychological testing*. New York: Macmillan.
- Ardila, A. (1995). Directions of research in cross-cultural neuropsychology. *Journal of Clinical and Experimental Neuropsychology*, 17, 143–150.
- Ardila, A. (2003). Culture in our brains: Cross-cultural differences in the brain–behavior relationships. In A. Toomela (Ed.), *Cultural guidance in the development of the human mind* (pp. 63–86). Westport, Connecticut: Ablex Publishing.
- Ardila, A., & Keating, K. (in press). Cognitive abilities in different cultural contexts. In B. Uzzell, M. Pontón, & A. Ardila (Eds.), *International handbook of cross-cultural neuropsychology*. Erlbaum: Mahwah, NJ.
- Ardila, A., & Moreno, S. (2001). Neuropsychological evaluation in Aruaco Indians: An exploratory study. *Journal of the International Neuropsychological Society*, 7, 510–515.
- Ardila, A., Ostrosky, F., & Mendoza, V. (2000). Learning to read is much more than learning to read: A neuropsychologically-based learning to read method. *Journal of the International Neuropsychological Society*, 6, 789–801.
- Ardila, A., & Rosselli, M. (2003). Educational effects on the ROCF performance. In J. Knight, & E. Kaplan (Eds.), *Rey-Osterrieth Complex Figure Handbook* (pp. 271–281). New York: Psychological Assessment Resources.
- Ardila, A., Rosselli, M., & Rosas, P. (1989). Neuropsychological assessment of illiterates. Visuospatial and memory abilities. *Brain and Cognition*, 11, 147–166.
- Ardila, A., & Rosselli, M. (1994). Development of language, memory and visuospatial abilities in 5 to 12-year-old children using a neuropsychological battery. *Developmental Neuropsychology*, 10, 97–120.
- Arnold, B. R., Montgomery, G. T., Castaneda, I., & Longoria, R. (1994). Acculturation and performance of Hispanics on selected Halstead–Reitan neuropsychology tests. *Assessment*, 1(3), 239–248.
- Benton-Sivan, A. (1992). *Benton Visual Retention Test*. Odessa, FL: Psychological Assessment Resources.
- Bernard, L. C. (1989). Halstead-Reitan neuropsychological test performance of black, Hispanic, and white young adult males from poor academic backgrounds. *Archives of Clinical Neuropsychology*, 4, 267–274.
- Berry, J. W. (1971). Ecological and cultural factors in spatial perceptual development. *Canadian Journal of Behavioral Sciences*, 3, 324–336.
- Berry, J. W. (1979). Culture and cognition style. In A. Marsella, R. G. Tharp, & T. J. Caborowski (Eds.), *Perspectives in cross-cultural psychology* (pp. 117–135). New York: Academic Press.
- Berry, J. W., Poortinga, Y. P., & Segall, M. G. H. (1992). *Cross-cultural psychology*. Cambridge: Cambridge University Press.
- Boivin, M. J., Giordani, B., & Bornefeld, B. (1995). Use of the tactual performance test for cognitive ability testing with African children. *Neuropsychology*, 9, 409–417.
- Brislin, R. W. (1983). Cross-cultural research in psychology. *Annual Review of Psychology*, 34, 363–400.
- Cattell, R. B. (1940). A culture free intelligence test. Part I. *Journal of Educational Psychology*, 31, 161–179.
- Cohen, R. A. (1969). Conceptual styles, culture conflict, and nonverbal tests. *American Anthropologist*, 71, 828–856.
- Cole, M. (1997). Cultural mechanisms of cognitive development. In E. Amsel, & K. A. Renninger (Eds.), *Change and development: Issues of theory, method, and application. The Jean Piaget symposium series* (pp. 250–263). Mahwah, NJ: Erlbaum.
- Cole, M. (1999). Culture-free versus culture-based measures of cognition. In R. J. Sternberg (Ed.), *The nature of cognition* (pp. 645–664). MIT Press.
- Cole, M., & Means, B. (1986). *Comparative studies of how people think*. San Diego, CA: University of California Press.
- Cornelius, S. W., & Caspi, A. (1987). Everyday problem solving in adulthood and old age. *Psychology of Aging*, 2, 144–153.
- Crampton, A., & Jerabek, I. (2000). *Culture-Fair IQ Test*. Plumeus Inc.
- Dawson, J. L. M. (1967). Cultural and physiological influences upon spatial perceptual processes in West Africa. Part 1. *International Journal of Psychology*, 2, 115–128.
- Evans, J. D., Miller, S. W., Byrd, D. A., & Heaton, R. K. (2000). Cross-cultural applications of the Halstead-Reitan batteries. In E. Fletcher-Jensen, T. L. Strickland, & C. R. Reynolds (Eds.), *Handbook of cross-cultural neuropsychology* (pp. 287–303). New York: Kluwer-Academic.
- Eviatar, Z. (2000). Culture and brain organization. *Brain and Cognition*, 42, 50–52.
- Ferguson, G. A. (1954). On learning and human ability. *Canadian Journal of Psychology*, 8, 95–112.
- Gay, J., & Cole, M. (1967). *The new mathematics and an old culture*. New York: Holt, Rinehart & Winston.
- Greenfield, P. M. (1997). You can't take it with you: Why ability assessments don't cross cultures. *American Psychologist*, 52, 1115–1124.
- Harris, M. (1983). *Culture, people, nature: An introduction to general anthropology* (3rd ed.). New York: Harper and Row.
- Hudson, W. (1960). Pictorial depth perception in subcultural groups in Africa. *Journal of Social Psychology*, 52, 193–208.
- Hudson, W. (1962). Cultural problems in pictorial perception. *South African Journal of Sciences*, 58, 189–195.
- Irvine, S. H., & Berry, J. W. (Eds.). (1988). *Human abilities in cultural context*. New York: Cambridge University Press.
- Jensen, A. (1980). *Bias in mental testing*. New York: Free Press.
- Klenberg, L., Korkman, M., & Lahti-Nuuttila, P. (2001). Differential development of attention and executive functions in 3- to 12 year old finish children. *Developmental Neuropsychology*, 20, 330–407.
- Klove, H. (1974). Validation studies in adult clinical neuropsychology. In R. M. Reitan, & L. A. Davison (Eds.), *Clinical Neuropsychology: Current status and application* (pp. 211–236). Washington, DC: Winston.
- Kolb, B., & Whitshaw, I. (1990). *Fundamentals of Human Neuropsychology* (3rd ed.). New York: W.H. Freeman and Co.

- Korkman, M. (2001). Introduction to the special issue on normal neuropsychological development in the school-age years. *Developmental Neuropsychology*, 20, 325–330.
- Korkman, M., Kirk, U., & Kempt, S. L. (1998). *NEPSY-A Developmental Neuropsychological Assessment*. San Antonio, TX: Psychological Corporation.
- Laboratory of Comparative Human Cognition (1983). Culture and cognitive development. In: P. Mussen (Ed.), *Handbook of child psychology: History, theory and methods* (Vol. 1, pp. 342–397). New York: Wiley.
- Leon-Carrion, J. (1989). Trail making test scores for normal children: Normative data from Spain. *Perceptual and Motor Skills*, 68, 627–630.
- Lezak, M. (1995). *Neuropsychological assessment* (3rd ed.). New York: Oxford University Press.
- Matarazzo, J. D. (1972). *Wechsler's measurement and appraisal of adult intelligence*. New York: Oxford University Press.
- Miller, R. J. (1973). Cross-cultural research in the perception of pictorial materials. *Psychological Bulletin*, 80, 135–150.
- Mitrushina, M. N., Boone, K. B., & D'Elia, L. F. (1999). *Handbook of Normative Data for Neuropsychological Assessment*. New York: Oxford.
- Morris, J. C., Heyman, A., Mohs, R. C., Hughes, J. P., van Belle, G., Fillenbaum, G., Mellits, E. D., & Clarck, C. (1989). The consortium to establish a registry for Alzheimer's Disease (CERAD). Part I. Clinical and neuropsychological assessment of Alzheimer's disease. *Neurology*, 39, 1159–1165.
- Mulenga, K., Ahonen, T., & Aro, M. (2001). Performance of Zambian children on the NEPSY: A pilot study. *Developmental Neuropsychology*, 20, 375–384.
- Nussbaum, N. L., & Bigler, E. (1997). Halstead-Reitan neuropsychological batteries for children. In C. R. Reynolds, & E. Fletcher-Janzen (Eds.), *Handbook of clinical child neuropsychology* (pp. 219–236). New York: Plenum Press.
- Nell, V. (2000). *Cross-cultural Neuropsychological Assessment: Theory and Practice*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Ostrosky, F., Ardila, A., & Rosselli, M. (1999). Neuropsi: A brief neuropsychological test battery in Spanish with norms by age and educational level. *Journal of the International Neuropsychological Society*, 5, 413–433.
- Osugi, O. N. (1882). Constructing complex geometric patterns. *Journal Of Cross-Cultural Psychology*, 13, 481–489.
- Perez-Arce, P., & Puente, A. (1996). Neuropsychological assessment of ethnic minorities. In R. J. Sbordone, & C. J. Long (Eds.), *Ecological validity of neuropsychological tests* (pp. 283–300). Delray Beach: GR Press.
- Reis, A., & Castro-Caldas, A. (1997). Illiteracy: A cause for biased cognitive development. *Journal of the International Neuropsychological Society*, 5, 444–450.
- Reynolds, C. R. (2000). Methods for detecting and evaluating cultural bias in neuropsychological tests. In E. Fletcher-Janzen, T. Strickland, & C. R. Reynolds (Eds.), *Handbook of cross-cultural neuropsychology*. New York: Kluwer Academic/Plenum Publishers.
- Rosselli, M., & Ardila, A. (1991). Effects of Age, Education and Gender on the Rey-Osterrieth Complex Figure 5, pp. 370–376.
- Rosselli, M., Ardila, A., Bateman, J. R., & Guzmán, M. (2001). Neuropsychological test scores, academic performance and developmental disorders in Spanish-speaking children. *Developmental Neuropsychology*, 20, 355–374.
- Rosselli, M., Ardila, A., & Rosas, P. (1990). Neuropsychological assessment in illiterates II: Language and praxic abilities. *Brain and Cognition*, 12, 281–296.
- Salmon, D. P., Jin, H., Zhang, M., Grant, I., & Yu, E. (1995). Neuropsychological assessment of Chinese elderly in the Shanghai Dementia Survey. *The Clinical Neuropsychologist*, 9, 159–168.
- Salmon, D. P., Riekkinen, P., Katzman, R., Zhang, M., Jin, H., & Yu, E. (1989). Cross-cultural studies of dementia: A comparison of Mini-Mental State examination performance in Finland and China. *Archives of Neurology*, 46, 769–772.
- Segall, M. H. (1986). Culture and behavior: Psychology in global perspective. *Annual Review of Psychology*, 37, 523–564.
- Unverzagt, F. W., Hall, K. S., Torke, A. M., Rediger, J. D., Mercado, N., Gureje, O., Osuntokun, B. O., & Hendrie, H. C. (1996). Effects of age, education, and gender on CERAD neuropsychological test performance in an African American sample. *The Clinical Neuropsychologist*, 10, 180–190.
- Vernon, P. E. (1969). *Intelligence and cultural environment*. London: Methuen.

### Further reading

- Morais, J., & Kolinsky, R. (2000). Biology and culture in the literate mind. *Brain and Cognition*, 42, 47–49.
- Shepard, I., & Leatham, J. (1999). Factors affecting performance in cross-cultural neuropsychology: From a New Zealand Bicultural Perspective. *Journal of the International Neuropsychological Society*, 5, 83–84.