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ADAPTATION OF THE BEHAVIORAL ASSESSMENT AND RESEARCH SYSTEM (BARS) FOR EVALUATING NEUROBEHAVIORAL PERFORMANCE IN FILIPINO CHILDREN

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Abstract

Neurobehavioral tests have long been used to assess health effects in exposed working adult populations. The heightened concern over the potential impact of environmental exposures on neurological functioning in children has led to the development of test batteries for use with children. There is a need for reliable, easy-to-administer batteries to assess neurotoxic exposure in children. One such test battery previously validated with Spanish- and English-speaking children ages 4 and older, combines computerized tests from the Behavioral Assessment and Research System (BARS) with non-computerized tests. The goal of the present study was to determine the feasibility of using standardized neurobehavioral tests in preschool and school-aged Filipino children. Test instructions were translated into the vernacular, Tagalog or Tagalog-English (“Taglish”) and some instructions and materials were modified to be appropriate for the target populations. The battery was administered to 4 to 6 year old Filipino children (N=50). The performance of the Filipino children was compared to data previously collected from Spanish- and English-speaking children tested in the US. The majority of children had no difficulty completing the tests in the battery with the exception of the Symbol-Digit test and Digit Span-reverse. The three groups showed similar patterns of performance on the tests and the older children performed better than the younger children on all of the tests. The findings from this study demonstrate the utility of using this test battery to assess cognitive and motor performance in Filipino children. Tests in the battery assess a range of functions and the measures are sensitive to age differences. The current battery has been utilized in several cultures and socio-economic status classes, with only minor modifications needed. This study demonstrates the importance of pilot testing the methods before use in a new population, to ensure that the test is valid for that culture.

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Keywords

Neurobehavioral Tests; Children; Cross-Cultural; Filipino; BARS

INTRODUCTION

Since the late 1960's behavioral performance tests have been used to assess the effects of neurotoxic occupational exposure in adult workers (Hanninen, 1966; Stewert, et al., 1968; Stewert, et al., 1969). The use of behavioral tests to assess workplace exposure has continued to increase and behavioral tests have become the most efficient methods (in terms of cost and time) to screen for adverse effects of neurotoxic exposures in adult workers (Anger, 2003; Anger, et al., 1994). These workplace studies have provided us with much of the current knowledge about the effects of toxicants on human neurological functioning (Anger, 1992; Anger, et al., 1993). The heightened concern over the potential impact of environmental exposures on neurological functioning in children has led to the development of neurobehavioral test batteries for use with children. There is a need worldwide, especially in developing countries with high levels of environmental and occupational exposures, for tools to detect adverse effects of chemicals.

Neurobehavioral Effects of Pesticide Exposure

There is concern about the impact of pesticide exposure on neurodevelopment. This is a major public health issue because of the increasing number of children exposed to these chemicals, and the simultaneous increase in the prevalence of childhood developmental, learning, and behavioral difficulties. Children are exposed to pesticides through diet and through residential and occupational use of pesticides. Children of agricultural workers are considered to have a higher risk of exposure to pesticides compared to the general populations because of the close proximity of their homes to the fields where pesticides are applied and from take-home exposure (Fenske, et al., 2002; Loewenherz, et al., 1997).

Different adult populations exposed to pesticides have shown neurobehavioral deficits. Organophosphate (OP) poisoned individuals have shown a consistent pattern of deficits when compared to a non-exposed or non-poisoned population on measures of motor speed and coordination, sustained attention, and information processing speed (Reidy, et al., 1992; Rosenstock, et al., 1991; Savage, et al., 1988; Steenland, et al., 1994; Wesseling, et al., 2002). Similarly, several studies have identified neurobehavioral effects in workers with long-term low-level exposure to pesticides. Neurobehavioral changes have been examined in different occupational groups chronically exposed to pesticides, including sheep farmers (Steenland, 1996; Stephens, et al., 1995), green house workers (Bazylewicz-Walczak, et al., 1999), tree-fruit workers (Fiedler, et al., 1997), orchard pesticide applicators (Daniell, et al., 1992) and cotton workers (Farahat, et al., 2003). These studies have also found deficits in measures of sustained attention, information processing speed, and reaction time.

Studies examining preschool children found deficits associated with living in an agricultural community and parent's working in agriculture (Guillette, et al., 1998; Handal, et al., 2007; Rohlman, et al., 2005). These studies were conducted in different countries and used different methods, but all showed performance deficits. An anthropological study of children in Mexico found that children living in an agricultural area showed impaired stamina, coordination, memory, and capacity to represent a familiar subject in drawings (Guillette, et al., 1998). Performance differences were also seen between children in the US whose parents work in agriculture compared to those not working in agriculture on response speed and coordination (Rohlman, et al., 2005). A study of children living in Ecuador found that children living in a communities with a high potential exposure to pesticides because of the presence of cut-flower

industry, demonstrated developmental delay compared to children living in communities with low potential exposure to pesticides and they scored lower on gross and fine motor skills and socio-individual skills (Handal, et al., 2007). Furthermore there was a link between malnutrition (as measured by stunting) and worse performance.

Deficits on neurobehavioral performance associated with pesticide exposure were also seen in school-age children. Two studies examined exposure early in the child's life, either prenatally (Grandjean, et al., 2006) or in the infant (Kofman, et al., 2006). Children whose mother had occupational exposure during pregnancy demonstrated visuospatial deficits (increased drawing score on Stanford-Binet copying test) and higher systolic blood pressure. Stunting was also associated with a lower score on the test. Current exposure, measured by urinary metabolites was also associated with longer reaction time latencies. Children who were hospitalized as infants because of exposure to OP pesticides had impaired long-term memory compared to controls (Kofman, et al., 2006). The exposed children demonstrated impairment during the acquisition phase of a verbal learning task and in inhibitory motor control. Exposure of 6 year old children or younger to methyl parathion spraying has been associated with difficulties performing tasks involving short-term memory and attention and more behavioral and motor skill problems than the unexposed children (Ruckart, et al., 2004).

By adolescence, children are often working in agriculture and exposure occurs occupationally. Studies have demonstrated performance deficits associated with children working in agriculture. Adolescent farm workers in Brazil showed impairment on several neurobehavioral measures including attention, response speed and coordination, when compared to children living in an urban area and not working in agriculture (Eckerman, et al., 2006). Although the sample size was small, younger children (10-11 years old) showed more impairment than older children. Adolescents working in agriculture in the US showed impairment on cognitive tests and response speed (Rohlman, et al., 2001a). Years working in agriculture and handling pesticides were also associated with worse performance in another adolescent population (Rohlman, et al., 2007c). These data provide preliminary evidence of neurodevelopmental delays in children exposed to pesticides.

Neurobehavioral Assessment of Children

Unlike adult neurobehavioral testing, in which a number of test batteries have been developed (see Anger, 2003 for a review), there have been very few attempts to develop specific neurobehavioral batteries for children. The Pediatric Environmental Neurobehavioral Test Battery or PENTB (Amler and Gibertini, 1996) is a test battery developed to assess possible neurotoxic effects in children living near hazardous waste sites. Recognized experts in the fields of neurotoxicology, epidemiology, neuropsychology, pediatrics, neurology, and psychology developed the battery. It combines observational measures and questionnaires for very young children with performance measures that are introduced for preschool and school age children. Although it was first introduced in 1996, the PENTB has thus far been used in only one study of children exposed to Methyl Parathion (Ruckart, et al., 2004). The performance measures included in the PENTB were developed for North American or European populations and need to be examined for cultural bias before being used in other populations.

Aside from the PENTB which was specifically developed to assess children, most research directed toward testing children has involved adaptations of neurobehavioral test batteries originally designed to test adults (Dahl, et al., 1996; Otto, et al., 1996; Rohlman, et al., 2001b) or tasks developed in the animal laboratory (Paule, et al., 1999). Tests that have detected neurotoxic effects in adults are appealing choices for similar studies in children because they have a proven ability to detect chemical exposure effects. One advantage of adapting adult tests for children is that these may allow comparisons across ages. Computer-based tests may

easily be adapted for use with children. Some of the modifications to parameters for computer-based tests used with adults include: (1) shortening the test duration; (2) increasing the stimulus display time and inter-stimulus interval; (3) changing the stimuli used from letters to animal shapes; (4) changing the presentation format from visual to auditory; and (5) using additional reinforcement during the test session (Dahl, et al., 1996; Otto, et al., 1996; Rohlman, et al., 2001b). These changes help to maintain the child's motivation during the test session.

Cross-Cultural Development

Most neurobehavioral tests used with adults and children have been developed in industrialized countries and have not been evaluated in ethnically and culturally diverse groups (Helms, 1992). The first step in preparing tests for a new culture or ethnic group is translation of the test instructions and materials into the new language. Although many tests do not require language for the child's performance on the tests, the instructions need to be adequately translated. Cultural variation also needs to be taken into account when translating tests into another language (Fletcher-Janzen, et al., 2000; Puente and Ardila, 2000; Rohlman, et al., 2001b). Stimuli or items used in tests may have more than one correct translation, especially when different local dialects are taken into account. This can cause problems interpreting responses and scoring the tests if naming the item is the correct response. Additionally, items or scenarios described in the test materials may be unfamiliar to the population being tested. It is important to translate the instructions and pilot test them in the population being studied and then make revisions until appropriate methods are developed.

The Behavioral Assessment and Research System

The Behavioral Assessment and Research System (BARS), a computerized test battery, was initially developed to assess neurotoxicity in adult populations that were non-mainstream, e.g., aging populations and working populations having varied educational levels and cultural backgrounds (Anger, et al., 1996; Rohlman, et al., 1996; Rohlman, et al., 2003). This was achieved by incorporating step-by-step instructions broken down into basic concepts, a "smiling face" used to reinforce performance, adjustable parameter settings, and a durable response unit with nine buttons placed over the keyboard to simplify responding. The same principles that applied to developing tests for adult populations with limited education were used to develop an effective testing system for children whose parents work in agriculture.

Development of the Current Battery

A battery of tests was assembled that combined measures that had demonstrated sensitivity to organophosphate (OP) exposure and, because of the unknown nature of effects of OPs in children (at the time of development), to assess a wide range of neurobehavioral functions. The battery was assembled by combining computerized tests from the BARS, tests adapted from the PENTB, and a test of recall and recognition, the Object Memory test (Mahurin, et al., 1992). The neurobehavioral tests and functions assessed are shown in Table 1.

A multi-step process was used to develop the current test battery to assess neurobehavioral performance in preschool children (Rohlman, et al., 2000b; Rohlman, et al., 2001b). Parameter settings for the computer-based tests (e.g., number of trials, difficulty level) that would be appropriate for young children were initially assessed in English-speaking preschool children (Rohlman, et al., 2000b). During this stage of test development we were interested in the strategies or methods the children were using to complete the tests and the percentage of children that were able to complete these tests. Based on the performance of these children, modifications were made to the original test battery and parameter settings.

The second step was to evaluate the modified battery for Spanish-speaking children. The test instructions and materials were translated into Spanish and pilot tested. Although the children

had no trouble completing some of the computer-based tests (Finger Tapping, Match-to-Sample, Digit Span forward), there were still problems with the Symbol-Digit test, the reverse trial of the Digit Span test, and completing the practice trial of the Continuous Performance Test. The Spanish-speaking children were also unfamiliar with the rhyme used for the Divided Attention Test. In this test the children are required to recite a nursery rhyme (“Jack and Jill” in the PENTB version) while simultaneously tapping. Because there is no Spanish equivalent of this rhyme, the “Itsy Bitsy Spider” or “La Araña Pequeñita” was used.

Similar to the English-speaking children, the Spanish-speaking children had no difficulty with the Purdue Pegboard test. However, some of the items in the Object Memory test were unfamiliar to the children (e.g., whistle). The unfamiliar items in Object Memory were replaced and the Visual Motor Integration test from the PENTB was added to the battery. These steps demonstrate the pilot-revise-pilot process that is necessary to develop methods for testing children.

The goal of the present study was to determine the feasibility of using standardized neurobehavioral tests in preschool and school-aged Filipino children. This study examined whether the children understood the instructions and were able to complete the tests, if there were any changes needed to adapt the battery to the Filipino population, and if the battery was sensitive enough to detect moderate effects.

METHODS

Participants

Preschool and elementary school children from an agricultural town in the Bulacan province of the Philippines completed the neurobehavioral test battery. Children were randomly selected from an elementary school (6-year olds) or day care center (4-year olds) in the study site area in Bulacan, Philippines. This study was approved by the Institutional Review Boards at University of the Philippines and Wayne State University.

After informed parental consent, children between the ages of 46 and 80 months were enrolled in the study and administered the neurobehavioral battery. There were two groups of children, based on age, 4-years (n=22; mean age 52.4 months) and 6-years (n=28; mean age = 74.1 months). The 4-year old children were tested at the Bulacan Provincial Hospital and the 6-year olds in the Barasoain Elementary School. The majority of parents (69%) had obtained at least a high school degree. The majority of fathers (74%) worked as nonskilled laborers and the mothers were homemakers (76%).

Neurobehavioral Test Battery

Performance tests from the Behavioral Assessment & Research System (BARS) and other individual (non-computerized) tests have been combined to develop a brief battery that assesses multiple neurobehavioral functions in children from preschool age to adolescents (4 to 18 years). Table 1 lists the tests in the battery. Tests were selected to assess a variety of cognitive functions including motor speed and coordination, learning, memory, attention, and other executive functions. Many elements of the battery assess areas of psychomotor functions in children that have been shown to be adversely affected by pesticides in animal models (Aziz, et al., 2001; Eriksson, 1997; Moser, 1995, 1999; Ruppert, et al., 1983; Talts, et al., 1998).

The test battery in its present form has been standardized in a sample that included both English and Spanish speaking 4- to 6-year olds (Rohlman, et al., 2000b; Rohlman, et al., 2001b). The battery is individually administered, with instructions relying on demonstration and practice trials.

Translation Pilot Study

All of the tests in the battery were translated into the vernacular, Tagalog or Tagalog-English (“Taglish”). The translation was presented to the Philippine research team for review to ensure the instructions could be understood by 4 to 6 year old Filipino children. Written scripts of the translation were used to ensure uniformity in instructions among testers. A pilot study (n=4 Filipino children) was conducted to determine if the translations were appropriate and that the children could understand the instructions. Mothers were also asked to ascertain if their child could understand the instructions. Based on the findings, additional instructional changes were made. Instructions were generally shortened to allow for better understanding. The song in the Divided Attention Test was changed from “Itsy Bitsy Spider” to “Happy Birthday” which all children knew. Several items in the Object Memory Test were also replaced. Two items, mirror and eyeglasses are called by the same name in Taglish; therefore, a shoe replaced the eyeglasses. The book was also changed to a notebook to further distinguish it from other items. Similar changes had been made in the Spanish translation (Rohlman, et al., 2000b; Rohlman, et al., 2001b).

Following these modifications the current study was conducted (N=50 children) to determine the feasibility of using this battery of tests with Filipino children.

RESULTS

During the initial stages of test battery selection one goal was to determine if children from the Bulacan Filipino population would be able to successfully complete the test battery. Success was defined as test completion in a timely manner as well as having meaningful performance data (e.g., performance within reasonable ranges and adequately above floor values, since environmental exposures can be predicted to drive down performance on many tests). Means and standard deviations for the administered tests are presented in Table 2. To better evaluate the results, comparative data for two additional cohorts (4 to 6 year-old Spanish-speaking and English-speaking samples, both from the United States) are provided for most of the tests administered (Rohlman, et al., 2001b). A cell-means model (Searle, 1993) was used to address whether group, age, or their interaction was significant. This approach was taken because the data are greatly unbalanced, a situation that leads hypothesis tests from the usual two-way ANOVA to become dependent on observed sample sizes. When a significant effect was found for group, the Tukey-Kramer post-hoc procedure (Miller, 1997) was applied to determine specific differences among the three groups. For all tests, a *p*-value less than 0.05 was considered significant. Effect size was quantified in terms of eta-squared, which is the proportion of the total sum-of-squares for the given performance measure that can be attributed to the indicated effect (group, age, or the interaction).

Test Completion

All of the Filipino children were able to complete all tests with the exception of the Symbol-Digit Test and Digit Span-reverse (Table 2). Only 2 of the 4-year old children were able to complete Symbol Digit, while all 4-year olds and nearly half of the 6-year olds had difficulty with the Digit Span Reverse. These findings are similar to the results found with Spanish- and English-speaking American preschool children (Rohlman, et al., 2000a; Rohlman, et al., 2001b), with the exception of the Divided Attention test. The Spanish-speaking children had more difficulty completing the Divided Attention test than the children administered the battery in Taglish.

Test Performance

An examination of the types of responses and patterns of responding indicates that in general, the Filipino children were performing adequately on these tests (Table 2). For example, both

the Finger Tapping and Purdue Pegboard show a range of responses and variability in the data. The Divided Attention test demonstrates the expected pattern of results, fewer taps while reciting the rhyme and more words said while reciting the rhyme when not tapping. The Object Memory Test also demonstrates the expected pattern of results for a recall and recognition task, i.e., higher performance on recognition than recall.

Older children performed better than younger children on all of the neurobehavioral tests (Table 3), supporting the hypothesis that performance on neurobehavioral tests improves with age. This finding is similar to results found with Spanish-speaking children in the United States (Rohlman, et al., 2007a) and is consistent with previous research examining performance on cognitive tests.

No difference in performance among the three groups was found except on the Divided Attention and Object Memory Tests (The post-hoc tests revealed no significant difference between the groups on the Digit Span Test.) The Spanish-speaking children had the most difficulty with the Divided Attention Test; they recited fewer words and tapped more than the other groups during the test, performing significantly worse than other two groups. Their rate of tapping while singing showed that they had the most taps; so their attention appeared to be more focused on tapping than singing, probably due to their unfamiliarity with the song. The English-speaking group also had more difficulty with the rhyme than the Taglish-speaking group. The Spanish-speaking group also recalled and recognized fewer items on the Object Memory Test than the groups administered the battery in Taglish or English. An interaction between age and group was found on the Purdue Pegboard test. There was a greater difference between the 4-year olds and the 6-year olds in the group tested in Taglish on the mean number of pegs placed with the right hand (3.4 pegs) compared to the groups tested in English and Spanish (1.7 pegs).

An analysis of gender showed that males had lower performance scores than females on all measures except for Digit Span, although these findings were not significant. These results are similar to previously reported findings (Rohlman, et al., 2007a). Although there were approximately equal numbers of males and females in the Taglish and English-speaking groups (52% each), the Spanish-speaking group had only 23% females. Effect sizes were calculated for gender (male vs. female) using a d-prime and were all less than .50.

A retrospective power analysis found the observed power for the majority of performance measures to be sufficient (~80% or better) for effects with eta-squared of at least 10%; power exceeded 80% for Object Memory tests when eta-squared exceeded 8%. The Digit Span test had an observed power of 70% for testing the effect due to group, which explains why post-hoc tests failed to uncover a significant difference despite an overall p-value of 0.02. The observed power corresponding to interactions never exceeded 48%, except for the Purdue Pegboard test (right hand), which had 77% power.

DISCUSSION

This study demonstrated the utility of using this test battery to assess cognitive and motor performance in Filipino children. Tests in the battery assess a range of functions and the measures are sensitive to age differences. Filipino children were able to complete the majority of tests.

The findings from the Divided Attention Test suggest that using a rhyme (e.g., “Happy Birthday”) that is familiar to more children will improve test completion and performance on the test. Many of the Spanish-speaking children were not familiar with “La Araña Pequeñita” or “Itsy Bitsy Spider” and had difficulty remembering it during the test session (Rohlman, et al., 2001b). Allowing sufficient opportunities to practice the rhyme during the test session will

also improve the child's ability to recite the rhyme while tapping. Filipino children had difficulty completing two tests in the battery, Digit Span-reverse, and Symbol-Digit. These findings are similar to the Spanish- and English-speaking children (Rohlman, et al., 2001b). Although the children understood how to perform the Symbol-Digit test, they were not motivated to complete the multiple assessment trials. Older children were more likely to complete these tests (e.g., the percentage of Taglish-speaking children completing the Symbol-Digit test increased from 9% in the younger group to 75% in the older group). Although the percentage of children completing Digit Span-reverse also increased, the improvements were not as great (only 42% of the older children completed this test). Modifying the instructions may improve performance since previous research with school-age children in Brazil indicated that the children had difficulty with the wording of the instructions (Rohlman, et al., 2000b). Because of the low completion rate it is recommended that Symbol-Digit and Digit Span-reverse not be included as part of a battery for preschool children (Rohlman, et al., 2001b).

An examination of the performance data supports the hypothesis that performance on neurobehavioral tests improves with age. The older children performed significantly better than the younger children on every test. This is consistent with previous research examining performance on cognitive tests (Kail, 1991; Rival, et al., 2004). The speed of responding also improves with age, older children are faster, and the strategy that is being used by the children may also be changing as they have more experience with learning and testing in school situations.

The performance of the three groups of children showed only two measures that varied by group, Divided Attention and Object Memory. In both cases the children tested in Spanish performed worse than the children tested in English and Taglish, although the children tested in English did not recite as many words as the children tested in Taglish. The likely cause of this poorer performance is the rhyme and objects used in these two tests. Using a rhyme that more children are familiar with (e.g., "Happy Birthday") and selecting objects that are unambiguous should improve performance on these tests.

Performance tests from the BARS have been used in several studies of farmworkers and their families. The tests have detected performance differences between adolescents and adults working in agriculture and non-agricultural control groups. Modest performance deficits have been found in preschool children whose parents work in agriculture compared to children whose parents do not work in agriculture that are consistent with functional effects seen in adults exposed to low concentrations of OP pesticides (response speed and latency) (Rohlman, et al., 2005). Increased performance deficits were associated with increased years working in agriculture in adult and adolescent farmworkers (Rohlman, et al., 2007b). Adolescent farm workers in Brazil showed performance deficits associated with an index of exposure (Eckerman, et al., 2006). A positive correlation between urinary organophosphate metabolite levels and poorer performance on neurobehavioral tests in adult agricultural workers has also been reported (Rothlein, et al., 2006). These results and use of the battery in other populations, including preschool children (Chiodo, et al., 2006), indicate the potential utility of the battery in environmental health studies.

The current battery has been utilized in several cultures and socio-economic status classes, with only minor modifications needed. This study demonstrates the importance of pilot testing the methods in new populations, to ensure that the test is appropriate for that culture. As researchers attempt to compare the effects of various neurotoxic exposures on children around the world and there are more international collaborations, the ability to generalize neurobehavioral results by using this type of battery is crucial.

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Table 1

Description of neurobehavioral tests and functions in the battery developed for children.

Test	Function and Description
Digit Span (BARS)	Memory & Attention <ul style="list-style-type: none"> Spoken presentation of number sequences Forward and Reverse recall 2 chances at each span length
Finger Tapping (BARS)	Response Speed & Coordination <ul style="list-style-type: none"> Right and left hand tested Number of taps in 20 second duration
Match-to-Sample (BARS)	Visual Memory <ul style="list-style-type: none"> 15 Stimuli shown for 3 seconds Choose from 3 choices Delay between presentation and choice varies from 1 to 8 seconds
Cont. Performance (BARS)	Sustained Attention <ul style="list-style-type: none"> 75 shapes shown rapidly, 30 targets Pressed key when target (circle) was shown
Symbol-Digit (BARS)	Information Processing Speed <ul style="list-style-type: none"> Match symbol paired with number
Divided Attention (BARS/PENTB)	Divided Attention <ul style="list-style-type: none"> Tapped button while reciting nursery rhyme Right and left hand tested
Purdue Pegboard (PENTB)	Dexterity <ul style="list-style-type: none"> Number of small pegs placed in holes during 30 sec Right, left and both hand trials
Visual Motor Integration (PENTB)	Hand-Eye coordination <ul style="list-style-type: none"> Copied line drawings
Object Memory Test	Recall & Recognition Memory <ul style="list-style-type: none"> Shown 16 objects and asked to name Immediate and delayed recall Recognition test

Table 2

Means $\pm$ (SDs) for tests in the neurobehavioral battery for children administered in Taglish, Spanish, and English. In the left hand column, "Number Completed" refers to how many children in the sample were able to complete the test measure.

	Taglish			Spanish			English	
	4 years	6 years		4 years	6 years		4 years	6 years
Mean age in months	52.4 (2.5)	74.1 (4.4)		54.0 (3.8)	68.4 (7.7)		53.2 (3.9)	70.6 (7.3)
Finger Tapping								
Number Completed	22/22	28/28		9/10	6/7		15/15	16/16
Right Hand	44.0 (5.7)	56.2 (10.5)		48.0 (11.8)	59.8 (14.5)		44.8 (7.9)	54.0 (9.4)
Left Hand	40.0 (7.1)	46.5 (8.1)		43.7 (11.9)	53.5 (12.2)		37.8 (8.8)	46.8 (11.5)
Symbol-Digit								
Number Completed	2/22	21/28		--	--		--	--
Latency (msec)	8140.8 (1164.4)	6133.3 (1256.8)						
Digit Span – Forward								
Number Completed	15/22	28/28		6/10	6/7		14/15	14/16
Forward Score	3.5 (0.6)	4.1 (0.7)		3.7 (0.5)	3.7 (1.0)		3.9 (0.6)	4.6 (1.0)
Digit Span – Reverse								
Number Completed	0/22	12/28		2/10	3/7		5/15	13/16
Reverse Score	--	3.2 (0.4)		2.5 (0.7)	2.0 (0.0)		2.8 (0.4)	2.7 (0.5)
Divided Attention – No Song								
Number Completed	21/22	28/28		2/10	5/7		14/15	15/16
Tap Rate Right	2.5 (0.5)	3.0 (0.6)		3.1 (0.5)	3.5 (1.0)		2.6 (0.7)	3.1 (0.7)
Tap Rate Left	2.2 (0.5)	2.5 (0.5)		2.8 (0.9)	2.8 (0.8)		2.0 (0.5)	2.6 (0.5)
Divided Attention – Song								
Tap Rate Right	1.9 (0.4)	2.5 (0.6)		2.7 (0.8)	3.0 (1.0)		1.9 (0.7)	2.3 (0.8)
Tap Rate Left	1.8 (0.4)	2.2 (0.4)		1.8 (1.0)	2.7 (1.0)		1.7 (0.6)	2.2 (0.7)
Words Right Hand	1.1 (0.3)	1.3 (0.3)		0.4 (0.2)	0.6 (0.3)		0.9 (0.2)	1.0 (0.3)
Words Left Hand	1.4 (0.5)	1.7 (0.4)		0.5 (0.2)	0.6 (0.3)		1.0 (0.4)	1.2 (0.4)
Words No Tapping	1.3 (0.4)	1.5 (0.4)		0.4 (0.6)	0.8 (0.1)		1.1 (0.3)	1.2 (0.2)
Object Memory Test								
Number Completed	22/22	28/28		10/10	7/7		15/15	16/16
Name	14.2 (1.4)	15.1 (0.7)		13.9 (1.9)	14.4 (1.0)		15.1 (1.0)	15.5 (0.9)
Immediate Recall	4.8 (2.6)	7.1 (2.2)		3.3 (2.6)	5.0 (1.7)		4.5 (2.0)	5.4 (1.9)
Delayed Recall	4.6 (2.8)	5.7 (2.1)		2.2 (3.0)	5.1 (1.9)		3.9 (1.2)	4.4 (1.6)
Recognition	12.9 (3.9)	15.6 (0.7)		9.5 (7.6)	9.3 (7.5)		12.5 (5.2)	15.6 (0.8)
Purdue Pegboard								
Number Completed	22/22	28/28		10/10	6/7		15/15	16/16
Right Hand	7.7 (1.1)	11.1 (1.2)		8.3 (1.4)	10.1 (1.5)		8.6 (1.4)	10.4 (1.4)
Left Hand	7.0 (1.0)	9.6 (1.3)		7.5 (1.1)	9.3 (1.9)		7.7 (1.5)	9.8 (1.3)
Both Hands	5.0 (1.2)	7.9 (1.6)		5.2 (2.1)	7.5 (1.2)		6.0 (1.3)	7.4 (1.7)

Table 3

Results from an unweighted cell-means model testing the effect due to age, group, and the interaction between the two. Eta-squared is a measure of effect size and equals the proportion of the total sum-of-squares attributable to the indicated effect. Tukey-Kramer post-hoc procedure is used to identify differences among groups when effect was found to be significant.

	Group × Age		Group		Age		Comments
	eta-sq	p	eta-sq	p	eta-sq	p	
Finger Tapping							
Right Hand	0.004	0.78	0.019	0.31	0.204	<0.01	
Left Hand	0.005	0.75	0.044	0.10	0.139	<0.01	
Digit Span							
Forward Score	0.021	0.38	0.083	0.02	0.055	0.02	1
Divided Attention - No Song							
Tap Rate Right	0.002	0.90	0.040	0.14	0.057	0.02	
Tap Rate Left	0.023	0.33	0.048	0.10	0.035	0.07	
Divided Attention - Song							
Tap Rate Right	0.006	0.72	0.070	0.03	0.053	0.02	2,4
Tap Rate Left	0.008	0.68	0.015	0.47	0.112	<0.01	
Words Right Hand	0.002	0.88	0.290	<0.01	0.028	0.06	2,3,4
Words Left Hand	0.004	0.78	0.311	<0.01	0.018	0.13	2,3,4
Words No Tapping	0.009	0.60	0.235	<0.01	0.039	0.04	2,3,4
Object Memory							
Name	0.010	0.55	0.102	<0.01	0.056	0.01	2
Immediate Recall	0.017	0.36	0.078	0.01	0.090	<0.01	4
Delayed Recall	0.030	0.19	0.065	0.03	0.084	<0.01	4
Recognition	0.016	0.37	0.150	<0.01	0.034	0.04	2,4
Purdue Pegboard							
Right Hand	0.047	0.01	0.002	0.79	0.301	<0.01	5
Left Hand	0.008	0.50	0.010	0.42	0.324	<0.01	
Both Hands	0.032	0.09	0.005	0.68	0.264	<0.01	

¹ Post-hoc test found no significant difference among groups

² English differs from Spanish

³ English differs from Taglish

⁴ Spanish differs from Taglish

⁵ Significant interaction. Children age 6 score significantly higher than 4 year olds; for English and Spanish, difference is 1.7, but is 3.4 for Taglish.