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Verbal counting and spatial strategies in numerical tasks: Evidence from indigenous Australia

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Abstract

In this study, we test whether children whose culture lacks counting words and counting practices, use a spatial strategy to support enumeration tasks. Children from two indigenous communities in Australia whose native and only language (Warlpiri or Anindilyakwa) lacked counting words, were tested on classical number development tasks, and the results compared with children reared in an English-speaking environment. We found that Warlpiri- and Anindilyakwa-speaking children performed equivalently to their English-speaking counterparts. However, in tasks in which they were required to match the number of objects in a display, they were more likely to reconstruct part or all of the spatial arrangement of the target than were their English-speaking counterparts. Following John Locke's interpretation of users of similar American languages and in contrast with later Whorfian interpretations, we suggest that counting words may be strategically useful, but that in their absence, other task-specific strategies will be deployed.

Introduction

It has been argued that knowledge of the vocabulary of counting words (CW) is necessary for the possession of concepts of natural numbers, and their interpretation as cardinalities of sets (Carey, 2004). Without having this vocabulary, humans must depend on two innate systems of "core knowledge" (Feigenson, Dehaene, & Spelke, 2004) which enable concepts of exact number of four or fewer, but only concepts of approximate number above four. The strong Whorfian claim (of lingusitic relativism) is that language shapes the development of numerical concepts. As has been pointed out, these innate systems are inadequate for natural numbers, which entail that each number is a property of a set, each number has a unique successor, and that arithmetical operations can be defined recursively in terms of operations on sets (Giaquinto, 1995, 2001).

Recent support for the strong Whorfian position has come from two studies of Amazonian groups whose languages have very restricted number word vocabularies. In a study of one such group, the Pirahã, (Gordon, 2004) concluded "The present experiments allow us to ask whether humans who are not exposed to a number system can represent exact quantities for medium-sized sets of 4 or 5. The answer appears to be negative. The Pirahã inherit just the abilities to exactly enumerate small sets of less than 3 items if processing factors are not unduly taxing."

In a much more comprehensive study of another Amazonian tribe, the Mundurukú, ((Pica, Lemer, Izard, & Dehaene (2004) conclude that "Although the Mundurukú lack words for numbers beyond five, they are able to compare and add large approximate numbers, way beyond their naming range. However, they fail in exact arithmetic with numbers larger than 4 or 5. Our results imply a distinction between a universal system of number approximation, and a language-based counting system for exact number and arithmetic."

These authors were not the first to explore Amazonian peoples for evidence about numerical concepts. The English philosopher, John Locke, in *An essay concerning human understanding. II Chapter XVI*, reported that “Some Americans I have spoken with (who otherwise of quick and rational parts enough) could not, as we do, by any means count to 1000; nor had any distinct *idea* of that number” (Locke, 1690/1961). These “Americans” were the Tououpinambos, a tribe from the depths of the Brazilian jungle, “had no names for numbers above 5”. However, they can reckon beyond five “by showing their fingers, and the fingers of others who were present,” suggesting that a lack of counting words did not entail the lack of a concept of enumeration nor indeed the ability to represent numbers greater than 5 using other means,

Now Locke did admit that having counting words could be useful. Numbers beyond one, “the simplest” idea, should be assigned “a name or sign, whereby to know it from those before and after” since “without a name or mark to distinguish that precise collection, [it] will hardly be kept from a being a heap in confusion…Distinct names conduce to our well reckoning”. Nevertheless, the concepts of numerosities could be generated, without language, by repeating the concept of *oneness* since “by adding one to one, we have the complex idea of a couple” etc. and indeed “*addibility* of numbers … gives us the clearest and most distinct *idea* of infinity”. That is to say, the words can be a useful strategy for keeping the concepts of particular numerosities clear in the mind, but are not necessary for the development of those concepts.

However, it is crucial to distinguish possession of a concept of natural number as such, that is, the concept of cardinal number, from concepts of particular cardinal numbers, such as *sixness.* Piaget’s tests of the “conservation of number” were designed precisely to assess whether the child possessed the concept of (cardinal) number rather than the concept of a particular cardinality.

If CW are necessary for the concept of number, this implies that when the child is unable to give reliably, on request, four, five, or six objects, it follows, that he or she knows nothing about the mapping, and that these words will refer indiscriminately to numerosities greater than 3. That is, "six" will simply mean *a lot.* However, there is recent evidence that these children have a good understanding of the general concept since they understand the operations that will change number and those that will not. For example, in an experiment by (Sarnecka & Gelman, 2004), the child is shown six dolls going into a box and is then told that there are six dolls in the box. The child cannot give six dolls on request, and presumably cannot distinguish a set of six from a set of five. If the box is then shaken, and the child is asked how many dolls are in the box, they will typically say the number that was given to them. In this case, *six.* However, if a doll is added or taken away, then they will give a different number word: not the correct one, probably, since they do not know what these words mean, except that they denote the number of objects in the set. That is, they know that only number-changing manipulations of the target set will require a change of number word. This implies that they do possess a general concept of cardinal number, but they have not yet learned to link words denoting larger numbers to their numerosity. Of course, knowing that adding or removing a doll means that the number is no longer six, does not entail that they have a concept of sixness, or of fiveness or sevenness.

One way of understanding Locke's position is that CW are a useful strategy for identifying numerosities, since "without a name or mark to distinguish that precise collection, [it] will hardly be kept from a being a heap in confusion." Our question then is what will children without CW do when they have to distinguish "precise collections"? According to one view, there will be just confusion, since they will not have an idea of the numerosity of a precise collection. Alternatively, they may make use of another strategy that could help them keep track, rather in the way that Locke's Tououpinambos used their own and other people's fingers. It is worth noting that there is no evidence of gestural numbers in Australia, despite the widespread use of gestures for inter-language communication and also in taboo contexts (see Kendon, 1988, for a review).

In a previous paper, we reported findings from a study that investigated the numerical abilities of different groups of indigenous Australian children, many of whom possessed few number words in their languages (Butterworth, Reeve, Reynolds, & Lloyd, submitted). We found no relationship between the availability of number words and numerical ability (memory for counters, cross-modal matching, non-verbal addition and sharing). The failure to find performance differences was not due to the insensitivity of these tests, since one predictor variable was significantly related to performance: children's age. If CW were necessary for the development of exact number concepts, then children who lacked number words should not have achieved high levels of numerical competence, yet high levels of competence were achieved, especially in older children. Moreover, we found no discontinuity in children's accuracy in working with small and large numbers, often regarded as the signature of the two core systems operating without the aid of language. In short, we found no evidence for the claim that an absence of CW constrains the ability to operate on number. However, in our previous work we did not consider what cognitive strategies children might use to solve numerical problems in an absence of linguistic terms for numerical concepts.

There is evidence from the work of (Kearins, 1981) that indigenous Australians have excellent spatial memories, superior on test from non-indigenous subjects. One important test resembled Kim's game, where the subject had to remember the exact locations on a tray of assorted objects. It may be, therefore, that children without CWs will spontaneously make use of a spatial strategy to help with the task of remembering the numerosities of precise collections. Those who claim that language is an essential ingredient in the development of numerical concepts have tended to ignore the possibility that other representation systems (e.g., spatial systems) may also support the development of number concepts. This is a non-trivial issue. Whorfian-oriented theorists have tended to conflate linguistic referents about number with the concept of number itself. If it can be shown that non-verbal representation systems also support numerical concepts, it would seriously weakens the strong Whorfian position. Given that different representation systems (e.g., linguistic and spatial system) support numerical concepts, questions can be raised about how different representational systems interact to affect the acquisition of numerical concepts.

Consider a task in which the child needs to remember the number of objects in a display, for example if the task requires the accurate reconstruction of the numerosity of the display. If the child has mastered the count list and the cardinality principle (Gelman & Gallistel, 1978), one efficient way of doing this is to enumerate the elements of the set by verbally counting, and hold the final count word in memory. However, this is not the only way of doing it. For example, the child can map each element onto a known set, for example, her fingers, and use that as a mnemonic. A third way is to use a strategy in which each item and its location is stored in memory, so that an accurate reconstruction of the set will conserve its numerosity. Of course, the child may not intend to recall the numerosity of the precise collection, but the effect will be to do this,

Which strategy a child uses is likely to depend not only the conceptual resources available to him or her, but also to the precise demands of the task. In particular, if the child does not possess CWs, then a verbal strategy is not available; if there is no experience of finger counting, then that strategy will not be used. If the display has memorable spatial characteristics, it is more likely that a spatial will be employed, especially if the first two strategies are not within the child's repertoire.

To imagine that the verbal strategy is the only one possible, or even the best, is a highly ethnocentric perspective. In fact, we may ask whether children who possess a conventional count list have a better memory for number, compared to those children who do not possess CWs.

In this study, we explored these questions with a very simple task, where the child is required to reproduce from memory number of counters placed on a mat. Each child was free to use whatever method they wished to complete the task. According to the Whorfian described above, children without CWs should be unable to the task accurately beyond 4. Even a more moderate position would imply that CWs at least help the child recall the numerosity better, Neither of these language-oriented positions would have anything to say about how the spatial arrangement of the counters would affect strategy choice. Nor would the language hypothesis have any predictions about the effectiveness of spatial strategies.

Thus, we investigated how children from different language settings remember sets of objects. Of particular interest is the degree to which (1) number word knowledge, (2) numerosity, (3) object arrangement, and (4) children's age, affects both the number of objects recalled and strategies used to recall objects. We also assesed the relationship between successful number recall and strategy-use.

Languages

In the study we report here, we contrasted three languages, Warlpiri, Anindilyakwa and English. Warlpiri, spoken in the Central Desert north and west of Alice Springs, Northern Territory (NT), is in the Pama-Nyungan language family, and is a classifier language with three generic types of number words: singular (“jinta”), dual plural (“-jarra”; “jirrama”), and greater than dual plural (“jirrama manu jinta”; “marnkurrpa”; “wirrkardu”; “panu”).

Anindilyakwa, probably unrelated to any other Australian language, is the major indigenous language spoken on Groote Eylandt. (It is also spoken in some small communities on neighbouring islands and on the nearby East Arnhem Land coast.). Like Warlpiri, Anindilyakwa is a classifier language, with nine noun classes and four possible number categories: (1) singular, (2) dual, (3) trial (which may in practice include four), and (4) plural (more than three). Anindilyakwa has a base-5 number system, apparently appropriated from the Macassan traders who visited the northern coast of Australia, including Groote Eylandt, from about the 17th century onward. It appears to be the case that the base-5 system is reserved for special cultural enumeration events (e.g., distributing turtle eggs to recipients). In Anindilyakwa, numerals are adjectival, and must agree with the nouns they qualify (Stokes, 1982). Since there are nine noun classes, enumerating in Anindilyakwa is complex. However, the number names are 1 (“awilyaba”), 2 (“ambilyuma” or “ambambuwa”), 3 (“abiyakarbiya”), 4 (abiyarbuwa”), 5 (“amangbala”), 10 (“ememberrkwa”), 15 (“amaburrkwakbala”), and 20 (“wurrakiriyabulangwa”). The word for 20 is invariable, i.e., it does not change its form in different grammatical contexts (Stokes, 1982). The Anindylakwan number system is not formally introduced to members of the community until they reach adolescence. Stokes observes that "In traditional Aboriginal society nothing used to be counted that was outside normal everyday experience. When asked for what purpose counting was used in the old days, *the old women who know the number names* [emphasis added] say that counting was used for turtle eggs." (Stokes, p. 39). She also maintains that "numerals in Anindilyakwa are adjectival. They are complicated by the number of noun classes [nine], because all adjectives must agree with the nouns they qualify." (p. 41) Although these languages contain quantifiers such as *few, many, a lot, several,* etc. these are not relevant number words since they do refer to exact numbers, and the theoretical claim is about exact numbers. Ordinals, such as *first, second, third,* would be more problematic. However, these words do not exist in either Warlpiri (Bittner & Hale, 1995)or Anindilyakwa (Stokes, 1982).

We also tested monolingual English-speakers in Melbourne at a school for indigenous children.

Participants

We tested 45 children aged 4 to 7 years: 20 Warlpiri-speaking children, 12 Anindilyakwa-speaking children, and 13 English-speaking children from Melbourne. Approximately half the NT children were 4- to 5-years old and half were 6- to 7 years-old.

Methods

Guidelines for ethical research in indigenous studies (Australian Institute of Aboriginal and Torres Strait Islander Studies, 2000) were followed in setting-up and conducting the study, as well as working with the communities. Research assistants spent approximately three weeks in the communities prior to data collection, in order to (1) become familiar with communities' social practices, and for the communities to become familiar with the RAs; (2) learn rudimentary aspects of the indigenous language; (3) instruct indigenous helpers in research practices; and (4) familiarize children with test materials. Western research practices were strange to the indigenous assistants who accommodated to them with humor, even though they would not interact with children in such ways. To acquaint helpers with research practices and to familiarize children with test materials (e.g., counters), *familiarization* sessions were conducted. Children played matching and sharing games using test materials (counters and mats). For the matching games, the interviewer put several counters on her mat, and children were asked to make their mat the same. Children had little difficulty copying the number and location of counters on the interviewer's mat.

In Willowra and Angurugu, bilingual indigenous assistants were trained by an experimenter to administer the tasks, and all instructions were given by a native speaker of Warlpiri or Anindilyakwa. Children completed three tasks: the experimental task, two control tasks, and the experimental task, memory for counters.

Control task: Remembering familiar objects. This task was designed to determine whether children could remember a set of common objects. Identical 24 cm x 36 cm mats, and identical pots each containing a set of twelve items familiar to the children as part of their physical and cultural environment. The items comprised a leaf, a twig, a stone, a bean seed, a piece of string, a small piece of paper with a drawing of a flower, a paper-clip, a bulldog clip, a plastic bread clip, a piece of spiral pasta, a 5 cent coin, and a bottle top. The interviewer placed the bottle top on her mat and, after about four seconds, covered her mat with a cloth. The child was to "make your mat like [interviewer's name]/mine". All children placed the bottle top on their mat. The child was then asked to look carefully. The interviewer then placed a sequence of different arrays of objects on her mat and, as in the practice trial, covered her mat with a cloth after approximately four seconds. Eight trials were used in the *Memory for Number of Familiar Items* task comprising two, three, four, and five objects. The interviewer presented the arrays in two conditions: (1) a predetermined non-canonical arrangement, and (2) a predetermined canonical arrangement.

Control task: Matching counters. This task was designed to ensure that children could follow instructions to copy accurately. It was thus constructed to determine whether children possessed the attentional competencies necessary to complete other tasks. Identical 24 cm x 35 cm mats, and identical pots containing 24 red counters, were placed in front of the child and the interviewer. The interviewer placed one counter on her mat and one counter on the child's mat. The child was asked whether the mats were the same. (All children indicated agreement.) The interviewer then placed a sequence of different arrays of counters on her mat and the child was asked to look carefully at the interviewer's mat and to "make your mat like [interviewer's name]/mine". The interviewer's array of counters remained in full view while the child attempted to copy the interviewer's array. Four trials were used in the *Matching Counters* task comprising two, four, three or five counters. The interviewer presented the arrays in a predetermined non-canonical arrangement. All children were able to produce the correct numerosity on most, if not all, trials, and generally copied the interviewer's spatial array with reasonable accuracy.

Memory for counters: Identical 24 cm x 35 cm mats and bowls containing 25 counters were placed in front of a child and the experimenter. The experimenter took counters from her bowl and placed them on her mat, one at a time in pre-assigned locations. Four seconds after the last item was placed on the mat, all items were covered with a cloth and children were asked by the indigenous assistant to *make your mat like hers.* Following three practice trials in which the experimenter and an indigenous assistant modelled recall using one and two counters, children completed 14 memory trials comprising two, three, four, five, six, eight or nine randomly placed counters. In modelling recall, counters were placed on the mat without reference to their initial location. Number and locations of children's counter recall were recorded. Fourteen trials were used in the *Memory for Number of Counters* task comprising two, three, four, six, eight, and nine counters. The interviewer presented the arrays in two conditions: (1) a predetermined non-canonical arrangement, and (2) a predetermined canonical arrangement, where the counters were arranged in geometrically-regular patterns (following Mandler & Shebo, 1982). The trials comprising non-canonical arrangements were always presented first. The number of counters used by children was noted to allow analysis of children's ability to re-represent both small and large numerosities.

Results

Two tasks (*Remembering Familiar Objects, Matching Counters*) assessed whether children had the prerequisite skills to complete the Memory for Counters task.

Remembering Familiar Objects. All children correctly selected the to-be-remembered objects from the large set of familiar objects (note: only n = 2 - 4 familiar objects were used in the task). However, not unexpectedly some of the children began to play with the larger set of objects once they had completed the memory test. Nevertheless, it was evident that children understood the purpose of the requirements of the memory task.

Matching Counters. With two minor exceptions, few children experienced difficulty putting the number of counters on their mat that matched the number of counters on the interviewer's mat. First, compared to their NT peers, the Melbourne children tended to ignore the location of the counters on the interviewer's mat when placing counters on their mats (however, this trend was not significant, $p > .1$). Second, some children made errors in matching large numbers of counters, particularly for random arrangements. However, deviations from the correct to-be matched number of counters tended to be small (± 1).

The findings from the *Remembering Familiar Objects* and the *Matching Counters* tasks suggest that all children, independent of site and age, had the prerequisite abilities to meaningfully complete the *Memory for Counters* task. Performance on the latter task was analysed in terms of (1) correct recall, and (2) the tendency to use a spatial recall strategy in correctly recalling counters.

Memory for Counters—Correct Recall. Figure 1 shows the average number of counters recalled correctly as a function of test site, children's age, the size of the test array (small or a large number of counters) and the organisation of the array (canonical or random array). Not unexpectedly children found it easier to recall correctly the number of counters in small array compared to large arrays (F (1, 40) = 96.50, $p < .001$). However, compared to their younger peers, older NT children correctly recalled the number of counters in larger arrays, but did not differ in their recall of counters in small arrays (F (1, 40) = 5.17, $p < .05$). Further, it is evident that overall children correctly recalled the number of counters in canonical compared to random arrays (F (1, 40) = 28.44, $p < .001$). Nevertheless, although young NT children did not differ in their recall of the number of counters in large canonical and random arrays, older NT children correctly recalled the number of counters in canonical compared to random arrays (F (1, 40) = 9.63, $p < .01$). It is worth noting that the three-way interaction between small/large arrays, canonical/random and young/old was marginally significant (F (1, 40) = 3.55, $p < .1$).

Figure 1 about here

Memory for Counters—Spatial Recall Strategy. Figure 2 shows the percentage frequency of spatial strategy-use for counters recalled correctly as a function of test site, children's age, the size of the test array (small or a large number of counters) and the organisation of the array (canonical or random array). (We focused on the spatial reconstruction strategies used in recalling correct, rather than incorrect, number for two reasons: (1) there were relatively few small number errors, and (2) identifying an "incorrect spatial reconstruction" strategy is a contradiction in terms.)

Figure 2 about here

As can be seen by the frequencies cross tabulated in Table 2, young children in the NT used a spatial reconstruction strategy more often than children in Melbourne, χ^2 (3, N = 24) = 49.94, $p < .001$. Moreover, compared to the older NT children, young NT children used a spatial strategy more frequently, χ^2 (2, N = 32) = 8.09, $p < .01$. Further, young NT children used a spatial strategy irrespective of array format χ^2 (2, N = 15) = 1.25, *ns*; whereas, older NT children used a spatial strategy more often in recalling small, compared to large numerosity arrays, χ^2 (2, N = 17) = 18.52, $p < .001$. Finally, older NT children used a spatial strategy more often in recalling large canonical, compared to large random, numerosity arrays, χ^2 (2, N = 17) = 3.88, $p < .05$.

These findings suggest that the tendency to use a spatial reconstruction strategy to aid numerosity recall is associated with language community. It is evident the Melbourne children rarely relied on a spatial reconstruction strategy. Their NT peers, in comparison, tended to relied almost exclusively on a spatial strategy. Despite these strategy differences, the number of correct answers of Melbourne children and young NT children were similar for small and large numerosities.

Competency Profiles

Interestingly, the older NT children tended to use a spatial strategy less often than the younger NT children; and, they used it less often for random, compared to canonical number arrays. Why did older NT children use a spatial reconstruction strategy less often? Was it because of contact with English counting practices? Or, was it simply because they were more cognitively mature than the young children? To answer these questions we subjected correct performance on the array type x array size measures to a hierarchical cluster analysis (using Wards Method). The analyses yielded a three group solution, revealing three well-ordered competency profiles (see Table 1). Although on average older children performed better than younger children, children from both age groups appeared in each of the ability profiles (see Table 2). Moreover, on the basis of the data presented in Table 3 (and Figure 3), it is evident that the young NT children and the older NT children in the best performing profile (Cluster 3), used different strategies overall. The young children used a spatial reconstruction strategy for random and canonical arrays and for small and large arrays.

Tables 1-3 about here

In contrast, the older children's strategy profile varied as a function of task. Although caution should be exercised in interpreting the meaning of the findings because of the relatively small number of participants involved in the research, it appears the most competent young children used a spatial reconstruction strategy on all occasions to aid the recall of number. In contrast, the most competent older children (who were no more competent than the young children), used a variety of strategies to aid their recall of number. Of particular, interest is the use of a non-spatial strategy to recall the numerosity of large random arrays.

Figure 3 about here

Conclusions

In this study, no language effects were observed. Neither the Warlpiri-speaking nor Anindilyakwa-speaking children performed worse than the English-speaking children on any task. We did, however, find a significant difference in the use of spatial strategies in which NT children tried to reconstruct the exact spatial arrangement of the counters even though the task instructions did not require this. In fact, the demonstrations of how to do the task showed examples of correct answers that did not conserve the spatial lay-out of the counters. Moreover, among the younger NT children, the ones who performed most accurately – Cluster 3 – were the ones who always used a spatial strategy. The English-speaking children, by contrast, did not use this spatial strategy. It may be that if you have an effective verbal strategy, you will not use a spatial one.

Of interest is the degree to which strategies changes as a function of task factors (numerosity, spatial layout, linguistic group). All NT children tended to use spatial strategies to recall number more often for canonical compared to random arrays. And, older NT children tended to use spatial strategies less often than their younger peers, especially recalling the number of counters in random arrays. In short, compared to the Melbourne children, the NT children tended to adjust their memory-for-number strategy as a function changes in numerosity and spatial layout. The flexible use of strategies is intriguing: overall, it is not related to successful number recall, but only to changes in changes in task factors. Unlike the Melbourne children who tended to use a conventional number word memory strategy for all tasks, the NT children exhibited a range of strategies that seemed tailored to task context. We suggest that this particular finding shows that successful number recall can be achieved using a variety of mnemonic means, and as such is evidence against a strong Whorfian position.

We find little evidence to support a strong Whorfian position. We are not claiming that count words do not support numerical concepts, only that the quantification and computation system may not depend on these words per se. In short, we do not believe it profitable to regard linguistic referents for number as a proxy for number concepts. The rather general question of how CWs affect or interact with number and quantificaton in literate societies requires clarification. Although the acquisition of a stable list count words occurs early in development in many cultures, the appropriate use of count words in the service of enumeration is protracted. Furthermore, differences in cultural practices should not be regarded as synomymous with cognitive differences, even though different cultures might impose different cognitive constraints or offer different cognitive resources (e.g., verbal counting practices). We should not rule out the possibility that some concepts are universal, and a concept of cardinal number strikes us as a good candidate.

References

Bittner, M., & Hale, K. (1995). Remarks on definitenes in Warlpiri. In E. Bach (Ed.), *Quantification in Natural Languages.* (pp. 81-107). Dordrecht: Kluwer.

Butterworth, B., Reeve, R., Reynolds, F., & Lloyd, D. (submitted). The role of language in the development of numerical concepts: Evidence from indigenous Australian children

Carey, S. (2004). On the origin of concepts. *Daedulus*, 59-68.

Feigenson, L., Dehaene, S., & Spelke, E. (2004). Core systems of number. *Trends in Cognitive Sciences, 8*(7), 307-314.

Gelman, R., & Gallistel, C. R. (1978). *The Child's Understanding of Number* (1986 ed.). Cambridge, MA: Harvard University Press.

Giaquinto, M. (1995). Concepts and calculation. *Mathematical Cognition, 1*, 61-81.

Giaquinto, M. (2001). Knowing numbers. *Journal of Philosophy, XCVIII*(1), 5-18.

Gordon, P. (2004). Numerical cognition without words: Evidence from Amazonia. *Science, 306*, 496-499.

Kearins, J. (1981). Visual spatial memory of Australian Aboriginal children of desert regions. *Cognitive Psychology, 13*, 434-460.

Kendon, A. (1988). *Sign Languages of Aboriginal Australia: Cultural, semiotic and communicative perspectives.* Cambridge: Cambridge University Press.

Locke, J. (1690/1961). *An Essay concerning Human Understanding* (Based ofn Fifth Edition, edited by J. W. Yolton ed.). London: J. M. Dent.

Mandler, G., & Shebo, B. J. (1982). Subitizing: An analysis of its component processes. *Journal of Experimental Psychology: General, 11*, 1-22.

Pica, P., Lemer, C., Izard, V., & Dehaene, S. (2004). Exact and approximate calculation in an Amazonian indigene group with a reduced number lexicon. *Science, 306*, 499-503.

Sarnecka, B. W., & Gelman, S. A. (2004). Six does not just mean a lot: preschoolers see number words as specific. *Cognition, 92*(3), 329-352.

Stokes, B. (1982). A description of the mathematical concepts of Groote Eylandt Aborigines. In S. Hargrave (Ed.), *Language and Culture. Work Papers of SIL-AAB, Series B* (Vol. 8).

Table 1

Memory for Counters – Number of Children and Mean Correct Answers as a Function of Site, Age, and Cluster Membership

Site x Age	Cluster 1	Cluster 2	Cluster 3
		Number of Children	
Melbourne			
4- to 5-year-olds	9	1	3
Northern Territory			
4- to 5-year-olds	11	3	1
6- to 7-year-olds		7	10
		Correct Answers	
Melbourne			
4- to 5-year-olds	4.89	4.00	10.00
Northern Territory			
4- to 5-year-olds	5.64	8.33	10.00
6- to 7-year-olds		7.71	10.20

Table 2

Memory for Counters – Mean Correct Answers as a Function of Age and Cluster Membership

	Cluster 1	Cluster 2	Cluster 3
		Melbourne	
4- to 5-year-olds			
Small random	1.78	1.00	2.67
Small canonical	2.44	1.00	3.00
Large random	.11	.00	1.67
Large canonical	.56	2.00	2.67
		Northern Territory	
4- to 5-year-olds			
Small random		2.71	2.40
Small canonical		2.43	3.00
Large random		.14	2.20
Large canonical		2.43	2.60
6- to 7-year-olds			
Small random		2.00	1.80
Small canonical		2.29	2.40
Large random		.14	.60
Large canonical		1.43	1.40

Table 3

Memory for Counters – Percentage of Spatial Strategy-use as a Function of Site, Age, and Cluster Membership

	Cluster 1	Cluster 2	Cluster 3
Melbourne			
4- to 5-year-olds			
Small random	25	0	0
Small canonical	50	0	33
Large random	0	0	20
Large canonical	0	0	63
Northern Territory			
4- to 5-year-olds			
Small random	74	78	100
Small canonical	91	100	100
Large random	58	100	100
Large canonical	75	88	100
6- to 7-year-olds			
Small random		74	75
Small canonical		94	80
Large random		100	27
Large canonical		59	54

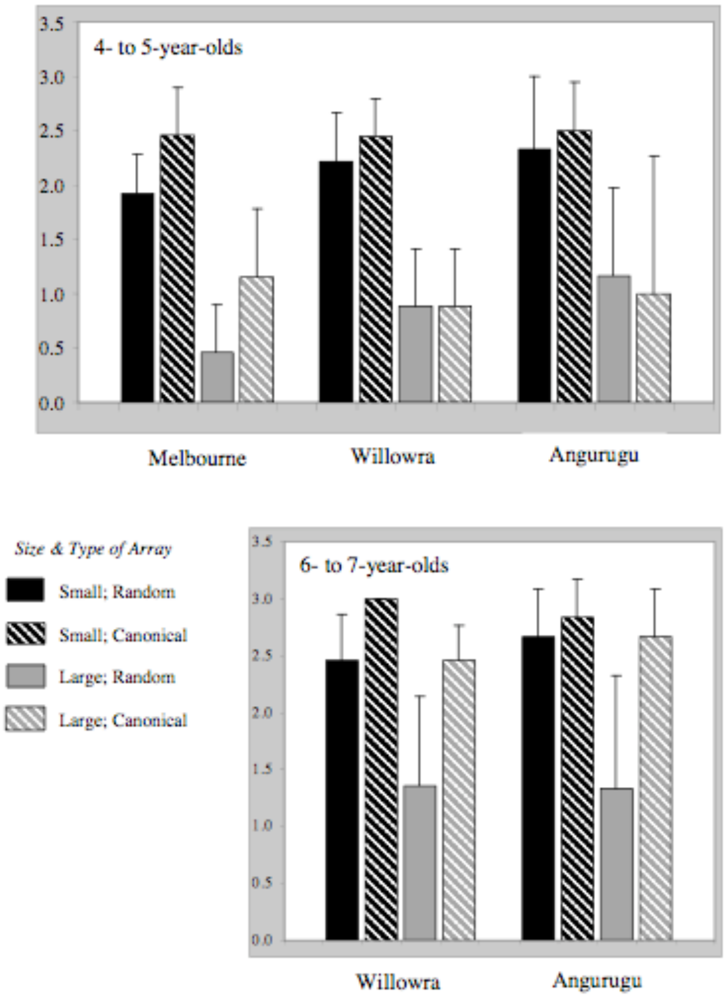

Figure 1. Average number of items recalled as a function of Site, Age, Size and Type of Array (Small/Large, Random/Canonical).

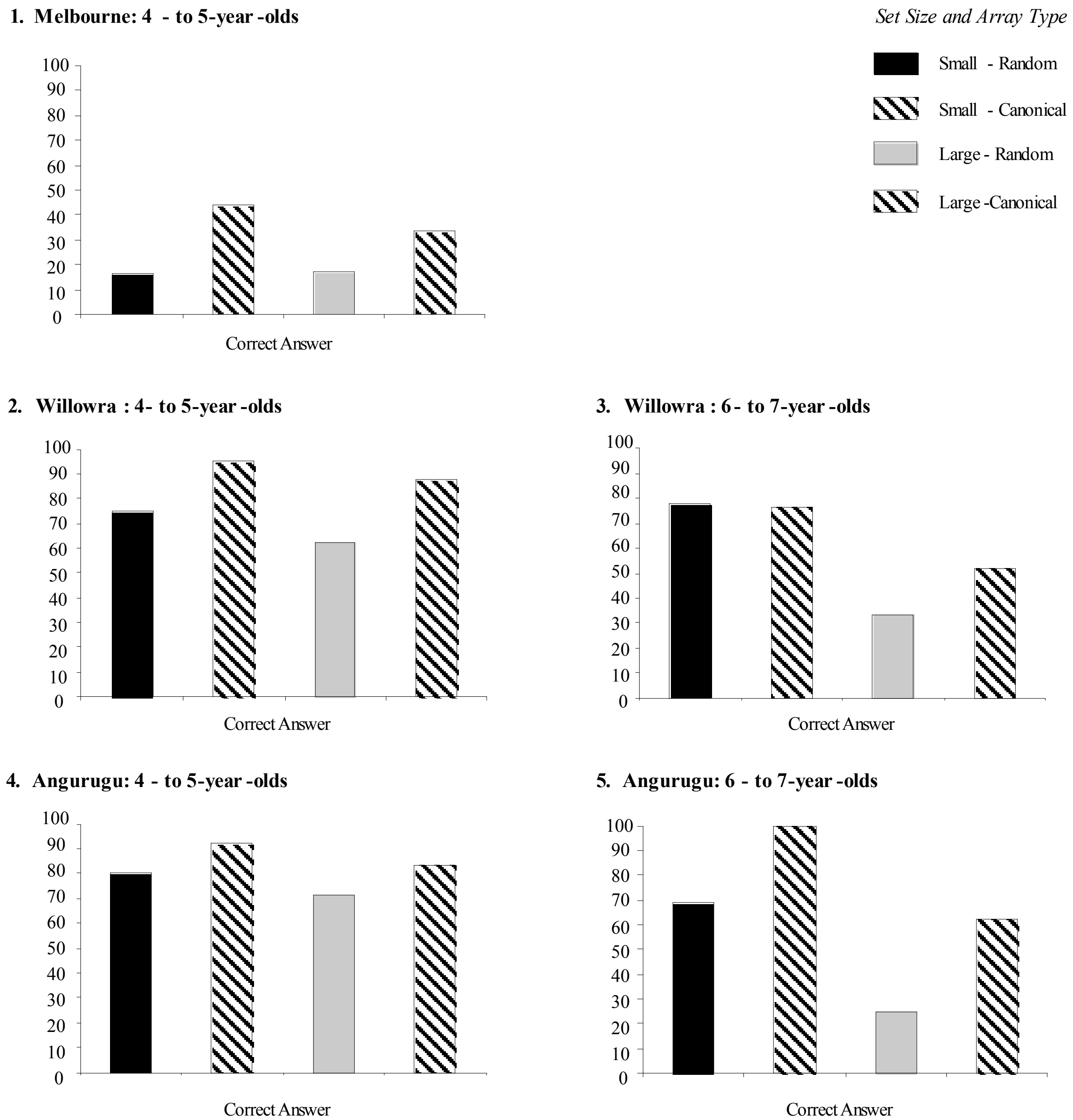

Figure 2. Percentage frequency of spatial strategy-use for correct answers as a function of Site, Age, and Type of Array (Small/Large, Random/Canonical)

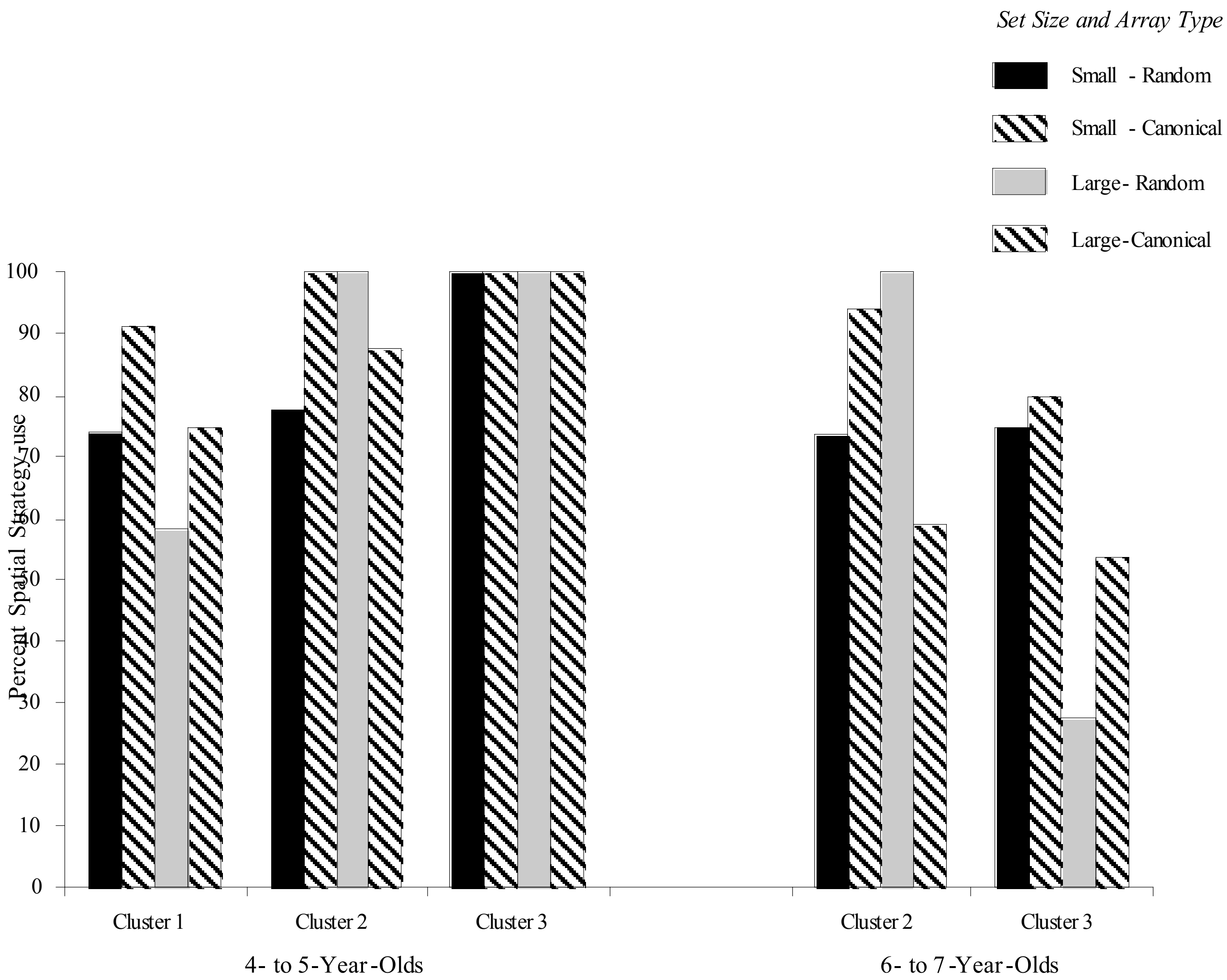

Figure 3. Percentage frequency of spatial strategy-use for correct answers as a function of Age, Type of Array (Small/Large, Random/Canonical), and Cluster Group membership (Northern Territory children only).