2004

Influences of Cultural Artifacts and Social Practices on Number Conceptualization in Adults: Experimental and Ethnographic Approaches to Everyday Numeric Cognition

Samar Zebian

American University of Beirut

INFLUENCES OF CULTURAL ARTIFACTS AND SOCIAL PRACTICES ON NUMBER CONCEPTUALIZATION IN ADULTS:

EXPERIMENTAL AND ETHNOGRAPHIC APPROACHES TO EVERYDAY NUMERIC COGNITION

Samar Zebian
American University of Beirut
Beirut, Lebanon

Traditionally, the adult numeric cognition literature, and more broadly the mathematical cognition literature, has given little consideration to the architectural and representational linkages between the semantic core of numeric representations and other non-numeric aspects of cognition. One predominating view is that numeric processors are insulated from other cognitive processes (McCloskey, 1992; McCloskey, Macaruso, & Whetstone, 1992; McCloskey, Sokol, & Goodman, 1986). Further developing this view, McCloskey argues that numeric decoding and production systems function independently of the numeric semantic system, i.e., the magnitude code. Many studies reinforce the view that the semantic properties of number concepts are autonomous and insulated from other non-numeric processes such as visual-spatial processing attention, inference, and reasoning. Taking this view further to consider other non-cognitive influences on the development of numeric thinking, it may seem justified to assume that this semantic core is not influenced, modified, or substantially mediated by the way we use and learn about numbers in the context of cultural artifacts or socially situated numeracy practices. This view is challenged by cultural psychologists.

Research inspired by cultural psychological approaches have shown how higher order mathematical thinking arises out of historic socio-cultural practices and is shaped by artifact use and goal-directed social and work practices (Ascher, 1991; Cole, Gay, Glick, & Sharp, 1971; Denny, 1986; Hatano, Amaiwa, Shimizu, 1987; Hutchins, 1995a, 1995b; Lave, 1977; 1988; Saxe, 1982,1985, 1991; Stigler, 1984). These researchers all begin with the assumption that quantitative thinking cannot be studied outside the physical and social contexts in which it functions because artifacts and social interaction place specific cognitive demands on numeric processes.

The main contributions from cultural approaches have shown that there are psychologically significant cultural contexts and cultural practices that influence the development of complex mathematical and numeric skills. However, and in contrast to the experimental math cognition tradition, cultural psychologists have not actively developed theories and empirical methods to investigate whether cultural practices affect basic on-line mathematical processes. As such, much can be gained from bringing together the cognitive science and the cultural approaches to mathematical thinking and number processing.

In the current investigations, I will examine two independent lines of research. The first set of studies assesses whether the directionality of different writing practices influences the properties of the mental number line. This line of research extends recent developments in the mathematical cognition literature which examines the relationship between numeric and spatial thinking. Dehaene (1992; Dehaene & Cohen 1995) offers empirical evidence, and a detailed computational and neurologically constrained model, which posits that number concepts have spatial properties which are automatically activated during any kind of quantitative processing, even in tasks that do not require access to the semantic magnitude code. These linkages between number and spatial position have been empirically investigated in a number of studies with English, French and Belgian participants who read and write from left-to-right. Results consistently show that numbers are conceptualized as points on an analogical number line, with small numbers on the left and larger numbers increasing towards the right (Bächtold, Baumüller, Brugger, 1998; Brysbaert, 1995; Dehaene, 1989; Dehaene & Akhavein, 1995; Dehaene, Bossini, & Giraux, 1993; Dehaene & Cohen, 1991; Dehaene, Dupoux, & Mehler, 1990; Fias, Lauwereyns, & Lammertyn, 2001). This association between numbers and points in space has been term the Spatial-Numerical Association of Response Codes effect, or the SNARC effect. The current investigations examine whether the left-to-right spatial orientation of the number line is found in individuals who use a right-to-left writing system. To follow up on and extend this research, the first series of studies will investigate whether the spatial orientation of the mental number line for Arabic monoliterates, who read and write from right-to-left, is different than that of English monoliterates. Additionally, the SNARC effect will be studied for the first time in Arabic-English biliterate groups and in an Arabic speaking illiterate group who can read numerals only.

The second line of research investigates another kind of non-quantitative influence on number conceptualization; the influence of socially situated literacy practices. The current studies extend Saxe's (1991) research into the mathematics of selling practice among Brazilian child candy street sellers. Saxe studied how numerical recognition skills are affected by the way sellers engage in socially situated math literacy (i.e., numeracy) on the job. In particular, Saxe examined how child street sellers, who practice orally-based paperless numeracy, named currency bills and Arabic numerals presented outside the context of currency. Saxe's main finding showed that orally-based sellers recognize number best when they appear on a currency bill or within another familiar visuo-spatial contexts, whereas free standing numbers (without a familiar visuo-spatial context) are not named as accurately.

The current two investigations extend Saxe's research in three ways. First, speeded rather than off-line number and bill recognition processes will be investigated for the first time. Second, the numeric skills of two adult seller groups, competent in a wide range of complex numeric and arithmetic skills, but who engage in orally-based versus paper-based numeracy practice will be compared. Third, the relationship between bill and numeral recognition processes and subsequent conceptualization processes will be studied in a number priming study. In the first study, herein referred to as the Bill and Numeral Recognition study, I investigated how quickly Traditional Lebanese sellers, who engage in orally-based paperless numeracy practices, recognize and name currency bills and Arabic numerals. The second group is a Modernizing Lebanese seller group who practices literacy-based numeracy which involves thinking about monetary values outside the context of currency. The second study herein referred to as the Large Number Concept Priming study, will investigate whether the speeded recognition processes observed in the first study are related to differences in number conceptualization.

Linkages between Spatial Processing and Number Conceptualization, and the Influences of Directionality of Writing

There is considerable research which shows the SNARC effect in individuals who read and write from left-to right (Dehaene & Cohen, 1990; Dehaene et al., 1993; Fias, 2001; Fias, Brysbaert, Geypens, & d'Ydewalle, 1996; Fias, Lauwereyns, Lammertyn, 2001; Reynvoet & Brysbaert, 1999).

However, only one known study attempts to explain why the mental number line has a left-to-right directionality. Dehaene et al. (1993) studied whether the directionality of one's writing system influenced the strength and direction of the SNARC effect among French monoliterates and French-Persian biliterates who use the French left-right system and the Persian right-left writing system. In this study participants pressed one of two keys depending on whether a numeral (flashed on a computer screen) was even or odd. In this study, evidence for the SNARC effect is revealed if participants are faster to judge small numerals with left-sided responses and large numerals with right-sided responses. Handedness effects were controlled. It is important to note that the parity judgment task used by Dehaene et al. does not require obligatory access to the magnitude of a number, nor to the number's position on the number line. Therefore, if the SNARC effect is observed in this conservative measure, it clearly indicates that the mental number line is automatically activated during various kinds of numeric processing.

Results of Dehaene et al.'s study showed a SNARC effect in French monoliterates and a weakened SNARC effect among highly skilled French-Persian biliterates who use both writing systems. These results suggest that Persian right-to-left literacy practices weaken the SNARC effect. However, strong claims cannot be made about the linkage between writing and number spatialisation without evidence from monoliterate groups who write and read only from right-to-left. Furthermore, data from illiterate subjects is needed to study whether the spatialisation of numerals is linked to the actual eye scanning movements and motor practices of reading and writing or to immersion in a literate culture.

Extending Dehaene et al's., line of research, the current investigations examined the influences of the Arabic right-to-left writing system on number conceptualization in three groups: an Arabic Monoliterate group who reads and writes from right-to-left, an Adult Arabic-English Biliterate group, an English Monoliterate group. Two additional groups, a Lebanese Illiterate group who could read numbers only and a Child Arabic-English Biliterate group, were investigated to examine how level of language skill affects the mental number line. The participants' task was to judge whether two numerals (flashed on a computer screen) had the same numerical value (e.g., 9 9; East Arabic numeral pairs: ٩ ٩) or a different numerical value (e.g., 1 9; East Arabic pairs: ١ ٩). To investigate the SNARC effect, I

compared the length of time it took participants to make judgments when the small number was on the left (e.g., 1 9; East Arabic pairs: ١ ٩) compared to when the small number was on the right (e.g., 9 1; East Arabic pairs: ٩ ١).

Results of SNARC Studies

Analysis of variance results from the Arabic Monoliterate group revealed, for the first time, a complete reversal of the SNARC effect (Reverse SNARC), such that small numbers were associated with the right side of space and large numbers were associated with the left side (see Table 1). This is the first known study to document the Reverse SNARC effect. The current findings are especially significant since neuropsychological studies and research on preliterate children show a left-right bias for spatial tasks.

Table 1

Oral Numeral Only SNARC Study: The Mean Length of Time in Milliseconds It Took Arabic Monoliterates, Arabic-English Biliterates, English Monoliterates, Lebanese Illiterates, and Child Biliterates to Make Left-Right and Right-Left Numerical Judgements

Groups	**Mean Raw Scores**		**Difference Score**
	left-right (i.e., 1 9)	**right-left (i.e., 9 1)**	
Arabic Monoliterates (n=19)	812 (106)	785 (112)*	27
Arabic-French Arabic-English Biliterates (n=17)	755 (126)	740 (125)	15
English Monoliterate (n=19)	764 (128)	775 (138)	-11
Illiterate (n=11)	926 (72)	910 (75)	16
Biliterate Child (n=8)	1080 (158)	1028 (194)*	52

* Denotes a significant difference between left-right and right-left responses as assessed by post hoc tests.

A secondary finding of the current investigation concerned the SNARC effect in the English Monoliterate group. The findings unexpectedly showed only a non-significant trend towards the SNARC for English Monoliterates (see Table 1). This finding contradicts findings from the parity judgment and numerical comparison tasks, and the one other same-different judgment task (Dehaene & Akhavein, 1995), all of which showed a significant SNARC effect for French and English Monoliterate participants. Most notably, the SNARC effect was observed in Dehaene and Akhavein's (1995) study which employed a bimanual same-different judgment task. Dehaene and Akhavein's task differed from the Oral Numeral Only SNARC task employed in the current study in two ways. First, recall that the stimulus pairs in Dehaene and Akhavein's study included different combinations of number words and numerals, whereas the stimulus in the current study included only numeral-numeral pairs. Second, Dehaene and Akhavein employed a bimanual task, whereas the current task required participants to orally respond to the target stimuli. Comparing Dehaene and Akhavein's result with the result of the Oral Numeral Only study, it is not possible to determine whether the non-significant trend towards the SNARC effect observed in the current study with English Monoliterates was due to one or more of these influences. Before more careful consideration is given to how these variables may affect the strength of the SNARC effect, a follow-up study which employed a task identical to the bimanual same-different judgment task used in Dehaene and Akhavein's (1995) study was conducted. In this study, 20 English Monoliterates were tested to determine whether Dehaene and Akhavein's results are replicable.

Analysis of variance results from the bimanual replication study, and from a second follow-up study which used the same stimulus but required verbal responding, showed that the strength of the SNARC effect for English Monoliterates is influenced by the requirement to make bimanual responses and the presence of number words in the stimulus (see Tables 2 and 3).

These task demands and how they interact with spatial processing have been explored systematically in previous research (Dehaene, & Akhavein, 1995; Dehaene, et al., 1993; Dehaene, et al., 1990). Further research is required to examine how the strength of the SNARC effect varies with task demands.

Table 2

Bimanual Replication SNARC Study: Mean Length of Time in Milliseconds It Takes Right Handed English Monoliterates to Make Left-Right and Right-Left Numerical Difference Judgment with Their Right and Left Hands When Presented with Four Types of Number Pairs: Number Word-Numeral, Number Word-Number Word, Numeral-Numeral, and Numeral-Number Word

Difference Judgment with Right Hand			
	Left-right	**Right-left**	**Difference Score**
Number word-Number word	441 (87)	449 (82)	-8
Number word-Numeral	418 (68)	442 (89)*	-24*
Numeral-Number word	424 (65)	427 (73)	-3
Numeral-Numeral	350 (59)	360 (69)	-10
Mean	408 (63)	419 (71)	-11
Difference Judgment with Left Hand			
	Left-right	**Right-left**	**Difference Score**
Number word-Number word	440 (67)	456 (82)	-16
Number word-Numeral	428 (71)	438 (82)	-10
Numeral-Number word	439 (81)	427 (65)	12
Numeral-Numeral	373 (86)	372 (78)	1
Mean	420 (72)	423 (71)	-3

Note. * significant difference ($p < .05$) between left-right and right-left responses, as assessed with simple main effect tests.

Table 3

Oral Version of Replication Study: Mean Length of Time in Milliseconds It Takes English Monoliterates to Make Left-Right and Right-Left Numerical Difference Judgment with Four Types of Number Pairs: Number Word-Numeral, Number Word-Number Word, Numeral-Numeral, and Numeral-Number Word

	Left-to-right	Right-to-left	Difference Score
Number word-Number word	614 (127)	615 (126)	-1
Number word-Numeral	579 (100)	621 (119)*	-42*
Numeral-Number word	599 (118)	596 (110)	3
Numeral-Numeral	534 (104)	510 (102)	24
Mean	581 (112)	585 (114)	-4

Note. * significant difference ($p < .05$) between left-right and right-left responses, as assessed by posthoc tests.

Currency Bill as Artifact in the Mathematics of Selling Practice

In studies which investigated numeral recognition, Saxe (1991) found that Brazilian child street sellers with little or no school-based literacy skills were not skilled at identifying and naming Arabic numerals presented in isolation without a currency bill context. Saxe observed this highly contextualized numeracy decoding skills in a wide range of numeric tasks involved in selling practice. However, the children could identify the same numerals when presented in the context of currency bills. Extending this line of work to adult populations and to on-line numeral recognition processes, the current series of studies examined the speeded bill and numeral recognition and conceptualization processes of two Lebanese Business Seller groups, a Traditional and Modernizing group. Ethnographic observations, conducted by the author, revealed pervasive differences in the everyday numeracy practices of these seller groups. Traditional business persons engaged in numeracy practices that involved the direct use of currency bills (as opposed to written records and tabulations) in many mathematical operations, business transactions, and accounting practices. Considering the cognitive significance of these practices, it was

hypothesized that these numeracy practices would require strong linkages between the monetary value of the bill and its visual-spatial properties leading to different number conceptualization processes. In comparison, modernizing business persons performed a great deal of mathematical operations and accounting practices on paper such that numeric thinking often occurred outside the context of currency. As such it was predicted that Modernizing Sellers will show weaker linkages between the number concept and the visual-spatial properties of the currency bill. These two seller groups were in turn compared to two control groups with no business experience, a Traditional Non-Seller group and a second Modernizing Non-Seller group.

Bill and Numeral Recognition and Priming Tasks

The participant's task was a speeded naming task that required them to name the monetary value of different kinds of bills: Standard Bills, bills with their numerals occluded (Numeral Occluded Bills), and currency numerals that appeared without the body of the bill (Numeral-Only Bills). Recognition processes for each bill was assessed by examining the time it took participants to name the different types of bills. In the priming study, I examined the length of time it took participants to name Standard Bills that were either preceded by a Currency Numeral-Only bill, or by Numeral-Occluded Bill. These processes were assessed in a continuous priming situation where participants were presented with two kinds of prime-target pairs. In the Currency Numeral Only-Standard Bill prime-target pairs participants named Numeral Only bills which was either related or unrelated to a Standard Bill which they also named. A related bill was one that had the identical monetary value of the Standard Bill, and an unrelated bill had a different value. In the Numeral Occluded-Standard Bill prime target pairs, participants named a Numeral Occluded Bill followed by a related or unrelated Standard Bill. The study examined where there would be a priming effect in each of these priming conditions. In line with the standard priming study rationale, if a number concept's pattern of activation is related to, or overlaps, with the pattern of activation for a concept activated after the first concept, then higher levels of priming will result. Based on the ethnographic observations of Traditional and Modernizing Sellers' numeracy practices, I predicted that there would be significantly different levels of priming for the Numeral Occluded-Standard prime-tar-

get pairs compared to the Currency Numeral Only-Standard pairs among the Traditional and Modernizing sellers. The ethnographic observations suggested that Traditional Sellers have highly fused number concepts that involve linkages between the body of the bill and its numeric value. These linkages may not be as strong in the Modernizing group because they are accustomed to handling currency-based numerals outside the context of actual currency bills. As such the prediction is that both groups will show Numeral Occluded Standard Bill priming (due to high visual overlap), however, only the Modernizing group will show Currency Numeral Only-Standard Bill priming.

Looking first at the analysis of variance results from the speeded numeral recognition portion of the study (Study 2a), the results showed that both the Traditional Sellers and Non-Sellers were significantly more skilled at naming the Standard Bills compared to the Numeral Only Bills (see Table 4).

Table 4

Bill and Numeral Recognition Study: Naming Times in Milliseconds for the Standard, Numeral Occluded, Currency Numeral Only Bills, and Non-Currency Numeral Only Bills

Groups Bills	Standard	Occluded Bills	Currency Numeral Only Bills
Traditional Non-Sellers (n=10)	825 (54)	896 (63)	1033 (106)
Traditional Sellers (n=10)	724 (46)	797 (72)	871 (94)
Mean	774 (71.7)	846 (83)	952 (128)
Modernising Non-sellers (n=10)	774 (74)	849 (87)	908 (108)
Modernising Sellers (n=9)	670 (67)	739 (77)	803 (79)
Mean	722 (87)	794 (98)	856 (107)

These findings reveal that the visual-spatial properties of the bill are a context for numeric recognition processes. This strong emphasis on the context in which numerals are embedded is not observed in the two Modernizing groups, regardless of selling practice.

Table 5

Large Number Concept Priming Study: The Mean Length of Time in Milliseconds It Takes to Name a Standard Bill Preceded by a Related and Unrelated Numeral Occluded Prime Type and Currency Numeral Only Prime Type

Groups		Numeral Only Priming	Numeral Occluded Priming
Traditional Non-sellers (n=10)	related primes	848 (67)	800 (92)
	unrelated primes	824 (71)	819 (55)
	Priming Effect	+24	-19
Traditional Seller (n=10)	related primes	749 (43)	675 (52)
	unrelated primes	731 (47)	745 (70)
	Priming Effect	+18.02	-70*
	Mean Related Prime	798 (47)	738 (56)
	Mean Unrelated Prime	777 (47)	782 (47)
	Mean Priming Effect	+21.07	-45
Modernizing Non-sellers (n=10)	related primes	774 (81)	750 (100)
	unrelated primes	784 (68)	789 (75)
	Priming Effect	-10	-39*
Modernizing Sellers (n=9)	related primes	664 (66)	639 (63)
	unrelated primes	695 (80)	680 (67)
	Priming Effect	-31*	-41*
	Mean Related Prime	719 (49)	695 (58)
	Mean Unrelated Prime	739 (49)	735 (48)
	Mean Priming Effect	-20	-40

* Significantly faster naming times for the related compared to the unrelated condition as assessed by simple main effect tests ($p < .05$)

Turning to the results of the priming study, Numeral Only Bills primed Standard Bills only for the Modernizing Sellers (see Table 5). This finding suggests that written numeracy practices lead to the skill of handling monetary values outside the context of currency. The other priming result which assessed whether the body of a currency bill (with its num-

bers occluded) could prime the whole bill, showed that the Traditional Sellers, and Modernizing Sellers and Non-Sellers who have most experience with currency, show significant levels of this type of priming. The Traditional Non-Seller group, most of whom were home makers who had the least experience with currency, was not primed by the body of the bill. Results of these studies show that the most automatic processes of recognition and conceptualization are influenced by everyday numeracy and literacy practices which on the surface may not seem to have implications for on-line numeric processing. As such the findings show how orally based numeracy practices motivate the development of specific kinds of numeric thinking which involve tight linkages between number concepts and artifacts. Whereas paper-based numeracy practices motivate and give rise to number concepts that show weaker linkages and associations with the visuo-spatial properties of currency.

Theoretical Significance of Cultural Approaches to Numeric Cognition

A cultural psychological approach to numeral cognition and mathematical thinking in general, is for the most part absent from the math cognition literature which has traditionally focused on what may seem to be the culturally invariant aspects of mathematical and numeric architecture (Dehaene, 1992; McCloskey, 1992). In addition to its acultural approach, the adult math cognition literature has given comparatively little consideration to how numeric and non-numeric aspects of cognition get linked and coordinated (some exceptions apply for some processes, see Campbell, 1994; Dehaene, 1992). A similar emphasis on the autonomy and separateness of numeric thought is found in much of the infant and animal cognition literature (see Gallistel & Gelman, 1992; Roberts, 1998; Wynn, 1998).

These research traditions contrast with cultural approaches which have shown how mathematical thinking arises out of the same historic socio-cultural processes and cultural practices that shape non-quantitative thinking (Ascher, 1991; Cole, Gay, Glick, & Sharp, 1971; Denny, 1989; Hatano, Amaiwa, Shimizu, 1987; Hishitani, 1990; Hutchins, 1995a, 1995b; Lancy, 1978; Lave, 1977; 1988; Millroy, 1991; Saxe, 1982,1985, 1991; Stevenson & Stigler, 1992). However, despite the critical perspective cultural psychologists' offer, researchers have not actively developed theories

and empirical methods to investigate how cultural practices affect basic on-line mathematical processes. The current investigations introduce new methodologies to cultural studies of numeric thinking by combining experimental and ethnographic methods, revealing the interconnectedness of numeric and non-numeric thought and further reveal how these linkages develop in the context of specific cultural practices and artifact use.

References

Ascher, M. (1991). *Ethnomathematics: A multicultural view of mathematical ideas.* New York: Chapman and Hall.

Bächtold, D., Baumüller, M., & Brugger, P. (1998). Stimulus response compatibility in representational space. *Neuropsychologia,* 36, 731-735.

Brysbaert, M. (1995). Arabic number reading: On the nature of the numerical scale and the origin of phonological recoding. *Journal of Experimental Psychology: General, 124,* 434-452.

Cole, M., Gay, J. Glick, J. A., & Sharp, D. W. (1971). *The cultural context of learning and thinking: An exploration in experimental anthropology.* New York: Basic Books.

Campbell, J.I.D. (1994). Architectures for numerical cognition. *Cognition, 53,* 1-44.

Dehaene, S. (1989). The psychophysics of numerical comparison: A reexamination of apparently incompatible data. *Perception and Psychophysics, 45,* 557-566.

Dehaene, S. (1992). Varieties of numerical abilities. *Cognition, 44,* 1-42.

Dehaene, S., & Akhavein, R. (1995). Attention, automaticity, and levels of representation in number processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 314-326.

Dehaene, S., Bossini, S., & Giraux, P. (1993). The mental representation of parity and number magnitude. *Journal of Experimental Psychology: General, 122,* 371-396.

Dehaene, S., & Cohen, L. (1991). Two mental calculation systems: A case study of severe acalculia with preserved approximation. *Neuropsychologia , 29,*1045-1074.

Dehaene, S., Dupoux, E., & Mehler, J. (1990). Is numerical comparison digital? Analogical and symbolic effects in two-digit comparison. *Journal of Experimental Psychology: Human Perception and Performance, 16,* 626-641.

Denny, J. P. (1986). Cultural ecology of mathematics: Ojibway and Inuit Hunters. In M.P. Closs (Ed.), *Native American Mathematics* (129-180). Austin: University of Texas Press.

Fias, W. (2001). Two routes for the processing of verbal numbers: Evidence from the SNARC effect. *Psychological Research, 65,* 250-259.

Fias, W., Brysbaert, M., Geypens, F., & d'Ydewalle, G. (1996). The importance of magnitude information in numeric processing: Evidence from the SNARC effect. *Mathematical Cognition, 2,* 95-100.

Fias, W., Lauwereyns, J., & Lammertyn, J. (2001). Irrelevant digits affect feature-based attention depending on the overlap of neural circuits. *Cognitive Brain Research, 12,* 415-423.

Gallistel, C., & Gelman, R. (1992). Preverbal and verbal counting and computation. *Cognition, 44,* 43-74.

Hatano, G., Amaiwa, S., & Shimizu, K. (1987). Formation of a mental abacus for computation and its use as a memory device for digits: A developmental study. *Developmental Psychology, 23,* 832-838.

Hutchins, E. (1995a). *Cognition in the wild.* Massachusetts: MIT Press.

Hutchins, E (1995b). How a cockpit remembers its speed. *Cognitive Science, 19,* 265-288.

Lave, J. (1977). Cognitive consequences of traditional apprenticeship training in West Africa. *Anthropology and Education Quarterly, 8,* 177-180.

Lave, J. (1988). *Cognition in practice.* Cambridge: Cambridge University Press

McCloskey, M. (1992). Cognitive mechanisms in numerical processing: Evidence for acquired dyscalulia. *Cognition, 44,* 107-157.

McCloskey, M., Macaruso, P., & Whetstone, T. (1992). The functional architecture of numerical processing mechanisms: Defending the modular model. In J.I.D. Campbell (Ed.), *The nature and origins of mathematical skills* (pp. 439-537). Amsterdam: Elsevier.

McCloskey, M., Sokol, S., & Goodman, R. A. (1986). Cognitive processes in verbal-number production: Inferences from the performance of brain-damaged subjects. *Journal of Experimental Psychology: General, 115,* 307-330.

Reynvoet, B., & Brysbaert, M. (1999). Single digit and two digit Arabic numerals address the same semantic number line. *Cognition, 72,* 191-201.

Roberts, W. (1998). *Principles of animal cognition.* Boston: McGraw-Hill.

Saxe, G. B. (1982). Developing forms of arithmetical operations among the Oksapmin children in Papua New Guinea. *Developmental Psychology, 18,* 583-593.

Saxe, G. (1985). Effects of schooling on arithmetical understanding: Studies with Oksapmin children in Papua New Guinea. *Journal of Educational Psychology, 77,* 503-513.

Saxe, G. B. (1991). *Culture and cognitive development: Studies in mathematical understanding.* Hillsdale NJ: LEA.

Stigler, J. W. (1984). "Mental abacus": The effect of abacus training on Chinese children's mental calculation. *Cognitive Psychology, 16,* 145-176.

Wynn, K. (1998). Numerical competence in infants. In C. Donlan, (Ed.), *The development of mathematical skills* (pp. 3-25). East Sussex: Psychology Press.

Author Note

Research was conducted under the supervision of Dr. J.P. Denny while I was Ph.D. student in the Department of Psychology at the University of Western Ontario, London, Canada.

Author's e-mail address: **Samar.Zebian@aub.edu.lb**