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CROSS-CULTURAL COMPARISONS OF YOUNG CHILDREN'S EARLY NUMERACY PERFORMANCE: EFFECTS OF AN EXPLICIT MIDPOINT ON NUMBER LINE PERFORMANCE FOR CANADIAN AND CHINESE-CANADIAN CHILDREN

Comparaciones interculturales del rendimiento numérico temprano de niños pequeños: Efectos de un punto medio explícito en el desempeño en recta numérica en niños canadienses y chino-canadienses

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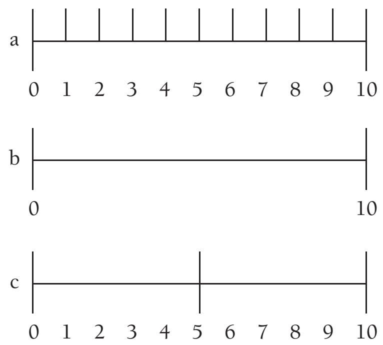
INTRODUCTION. Children's ability to place numbers on a line, where only the endpoints are marked, is related to other aspects of their mathematical understanding. In the present research, we examined the effects of a midpoint reference (e.g., marking the location of 5 on a 0-10 number line) on young children's performance (3- to 5-year-olds) on a number line task. **METHOD**. We compared children with shared educational experiences but different cultural backgrounds: Chinese-Canadian children (n = 47) and Canadian children whose parents were educated in Canada or elsewhere (n = 47). All children completed a standard condition with only the endpoints marked and a midpoint condition where a midpoint reference was presented on the number line. **RESULTS**. The early numeracy skills of Chinese-Canadian children were better than those of the other Canadian children. Chinese-Canadian children made more accurate number line estimates when a midpoint reference at 5 was provided compared to Canadian children whereas the groups did not differ on a standard number line (i.e., no midpoint).Cultural differences persisted when mothers' education, children's age, and kindergarten attendance were controlled. **DISCUSSION**. These results suggest that strong fundamental numeracy skills are related to children's performance on novel and complex tasks, such as the number line. These findings also indicate that differences across cultural groups may be related to language of instruction, parents' education, or differences in home activities and emphasize the importance of developing more comprehensive frameworks for interpreting cultural differences in mathematical performance.

Keywords: *Number line, Midpoint, Early numeracy, Chinese, Canadian, Children.*

Number lines are a common educational tool and are used extensively in research on children's early numeracy development (e.g., Ashcraft & Moore, 2012; Barth & Paladino, 2011; Laski & Siegler, 2007; LeFevre *et al.,* 2013; Muldoon, Simms, Towse, Menzies & Yue, 2011; Muldoon, Towse, Simms, Perra & Menzies, 2013; Schneider *et al.*, 2018). As shown in Figure 1a, bounded number lines capture the ordinal and proportional relations among numbers in a particular range. In the number-to-position version of the number line task (see figure 1b), children are required to estimate the position of a target number on a visual line where only the endpoints are labeled.

FIGURE 1. Examples of a number line with unit divisions (a), a number line typically used in research (b), and a number line with a midpoint reference as used in the present research (c)



Cross-cultural differences in Number Line Performance

Before they start grade 1, children educated in North America show poor performance on the number line task unless they have had training (Ramani & Siegler, 2008; Siegler & Ramani, 2008; Xu & LeFevre, 2016) especially compared to Chinese children (Laski & Yu, 2014; Siegler & Mu, 2008). For example, in two studies with a 0-100 number line task, five-year-old Chinese children were one to two years more advanced than five-year-old Americans (Laski & Yu, 2014; Siegler & Mu, 2008). In contrast, Muldoon *et al.* (2011) found that five-year-old Scottish children showed better performance on 0-10 and 0-20 number lines than four-year-old Chinese children, even when the two groups were matched on other aspects of their early numeracy performance. In that study, children's number line performance was only moderately correlated with other numeracy skills (cf. Siegler & Mu, 2008). Those findings indicate that educational experiences and/or developmental factors are potentially important in understanding children's number line performance.

Children from different countries may vary on many factors related to early numeracy skills (LeFevre, Cankaya, Xu & Jiménez Lira, 2018). Even in culturally homogenous samples, early numeracy performance is sometimes related to parents' education, intelligence, attitudes and beliefs about mathematics, income, children's educational background, or family socioeconomic status (e.g., Baharudin & Luster, 1998; Benavides-Varela *et al.*, 2016; LeFevre *et al.*, 2018; Niklas & Schneider, 2017; Zippert & Ramani, 2017). However, for the cross-cultural studies comparing Chinese children's number line performance to that of children in other countries, none reported any information about parents (Laski & Yu, 2014; Muldoon *et al.*, 2011; Siegler & Mu, 2008). In the present study we collected information about parents' education and children's attendance in kindergarten in order to determine whether these factors are related to group differences.

Number Line Strategies

Adults and children (from approximately age eight) use strategies on number line tasks that involve proportional reasoning, for example, estimating the midpoint of the line and placing their estimate in relation to this reference (Ashcraft & Moore, 2012; Barth & Paladino, 2011; Petitto, 1990; Slusser, Santiage & Barth, 2013; Sullivan, Juhasz, Slattery & Barth, 2011). In contrast, children in preschool or kindergarten (i.e., 3- to 5-year-olds) have limited proportional reasoning skills (Cohen & Sarnecka, 2014; Slusser *et al.*, 2013). Instead, they may use a strategy on the number line task in which they count from one of the end points to the target number (Pettito, 1990; Xu & LeFevre, 2016).

To effectively use a counting strategy, children need to know the counting sequence in the specified range of the number line, that is, the sequential relations among numbers (i.e., 9 comes before 10; Xu & LeFevre, 2016). For example, counting down from 10 is a more efficient way to place 9 on the number line than is counting up from 1. Thus, although young children are not expected to use proportional reasoning to estimate an implicit midpoint, they may have sufficient knowledge of numerical symbols and their sequential relations to use an explicit midpoint reference to refine their counting strategy. Xu and LeFevre (2016) found that preschool-aged children who received numerical training on sequential relations between numbers showed better performance on the number line with a midpoint reference than on the number line without a midpoint. This finding suggests that a midpoint reference is an effective scaffold for children who have the necessary skills but have not yet independently developed an effective strategy for successful number line performance. Similarly, research with older children suggests that reference points influence number line performance through their influence on strategy use (Peeters, Sekeris, Verschaffel & Luwel, 2017; Thompson & Opfer, 2010).

The Present Research

We presented number lines to 3- to 5-year-old children in two conditions: with or without a midpoint reference (see figure 1, b and c). We compared children whose parents were educated in China (i.e., Chinese-Canadian children) to children whose parents were not educated in China (i.e., other Canadian children). By comparing these two groups of children, we hoped to control the educational and cultural experiences of the children outside of their experiences at home. Previous research shows that Chinese children of immigrant parents have more experiences with numbers at home (Huntsinger, Jose, Liaw & Ching, 1997; cf. Sonnenschein *et al.*, 2012) and thus have stronger understanding of the number system than children from other cultures (e.g., Aunio, Aubrey, Godfrey, Pan & Liu, 2008).

In summary, we predicted that Chinese-Canadian children would have better early numeracy skills than other Canadian children (Hypothesis 1). We predicted that a midpoint reference would lead to better number line performance (Hypothesis 2; Xu & LeFevre, 2016). We also expected that only Chinese-Canadian children would show better performance on number line task with a midpoint reference compared to the standard version with only the endpoints indicated (Hypothesis 3). This hypothesis was based on the assumption that children with weaker early numeracy knowledge would not benefit from the midpoint reference (Xu & LeFevre, 2016). A range of early numeracy skills were assessed including rote counting, mapping between verbal and visual representations (e.g., digit naming), and manipulation of symbols and quantities (e.g., nonsymbolic arithmetic; KeyMath Numeration; Connolly, 2000). The largest differences between groups were expected on the more complex measures that required manipulation of symbols and quantities. A spatial span task was used to control for the effects of children's visual-spatial abilities on number line performance (Crollen & Noël, 2015). This research adds to the relatively sparse literature on the skills that support performance on number line tasks for young children.

Method

Participants

Ninety-four children were recruited and participated in the present study. All of the children had been born in Canada and were attending kindergarten or daycare in English in the same Canadian city. Chinese-Canadian children were recruited from a community group or through direct contact with parents, whereas the other Canadian children were recruited from four local daycares. Children who attended Kindergarten could have an advantage in terms of formal numeracy exposure compared to children who did not, and thus the percentage of children attending kindergartens was controlled in further analyses with respect to group differences. All measures were analyzed except for two extra tasks[1]. The two groups both ranged in age from 3:0 to 5:8 (years: months): Chinese-Canadian children, M = 50 months (SD = 9); other Canadian children, M = 51 months (SD = 11), $t(92) = .42$, $p = .673$. Forty-three percent of the Chinese-Canadian children were girls, as compared to 36% of the other Canadian children, χ^2 (1, N = 94) = .40, $p = .527$.

Parents were asked to indicate the frequency of speaking English and other languages at home based on a 5-point scale ("always" "often" "about half of the time" "sometimes" or "never"). Eighty-seven percent of the Chinese-Canadian children spoke Chinese at home "always" or "often"; the majority also spoke English at home either "sometimes" (55%) or "half of the time" or more frequently (41%). English was the language of the schools and daycares children attended and thus these children were bilingual. For the other Canadian children, 91% "always" or "often" spoke English at home. All of these children attended daycares or kindergartens where the language of instruction was English.

Information about parents' highest education level was available for 46 Chinese mothers, 45 Chinese fathers, 45 non-Chinese mothers, and 40 non-Chinese fathers. For Chinese-educated mothers (fathers), 39% (60%) had a post-graduate degree, 54% (40%) had an undergraduate degree, and 7% (0%) had a community college degree. Because there was little variability for Chinese fathers, the correlation between mothers' and fathers' education was low, $r(45) = .123$, $p = .420$; this lack of a correlation reflects that all parents were highly educated. For non-Chinese educated mothers (fathers), 16% (12%) had a post-graduate degree, 38% (38%) had an undergraduate degree, 33% (25%) had a community college degree, and 13% (17.5%) had a high school degree; 0% (7.5%) had less than high school. The correlation between mothers' and fathers' education for the non-Chinese parents was significant, $r(38) = .535$, $p< .001$. Education level was higher for Chinese than non-Chinese mothers, χ^2 = (1, N = 91) = 20.36, $p< .001$, and fathers, χ^2 = (1, N = 85) = 35.22, $p< .001$. The high education level of the Chinese-educated parents reflects Canadian immigration requirements such that applicants' work experiences, language proficiency, and education level are used as the major criteria to assess their eligibility. Because the education data were more complete for mothers, and because the Chinese fathers had very little variability in their highest level of education, whereas non-Chinese fathers had the most variability, we chose to use mothers' education in further analyses.

Although additional information was collected about parents' home activities with their children, only 53% of the non-Chinese parents responded, compared to 87% of the Chinese-educated parents. The children of the other Canadian parents who did not respond had weaker numeracy skills than those of parents who did respond. Due to the selection bias, questionnaire data are not discussed.

Procedure

Each child met individually with a female experimenter for a 20-minute session at a quiet space at the daycare centre, at a public library, at the authors' university, or at the child's home. All Chinese-Canadian children were tested in Chinese, whereas the other children were tested in English.

Measures

Number line task. Children were asked to complete a standard condition and a midpoint condition of a number line task: 24 children in each group did the standard condition first and 23 children did the midpoint condition first.

Children were presented nine separate sheets of paper, each with an identical 25-cm line, with "0" at the left end, and "10" at the right end. A target number was presented approximately 2 cm above the line in the top left hand corner of the page (e.g., NUMBER 2). The number line problems consist of nine randomly presented numbers (i.e., 1 to 9 inclusive for the standard condition; 5 was omitted for the midpoint version as it was shown on the line). The number line task was introduced as a racing game and children were asked to use a small animal sticker to indicate the estimated location for each target number. The size for all stickers was identical and the mid-point of each sticker was taken as the point of estimation for each trial. The experimenter explained the endpoints of the number line: "this is where 0 goes (pointing), the starting line; this is where 10 goes (pointing), the finishing line". Then, the child was asked to identify the target number N at the top of the page. If the child erred or failed to identify the number, the experimenter correctly named the number and asked the child to repeat it. The child was then asked to place a sticker on the line to show where the number N would go on the line. No feedback was given regarding the accuracy of their marks.

In the midpoint condition, the position of number 5 was shown on each number line (figure 1c). The instructions were the same as the standard condition except that the experimenter explained the midpoint reference to the child: "Do you know why 5 goes here?" If the child could not provide an explanation, the experimenter said, "It goes in the middle because it is half way between 0 and 10. The animal needs a water break here (holding the sticker at number 5)".

Rote counting. Children were asked to count from 1 through 20 early in the session. Near the end of the session, they were asked to count as high as possible, but were stopped at 100. Best count score was coded as the highest number correct up to the point of the second error across two attempts. The correlation between the two counting attempts was .55, $p< .001$. Children were also asked to count backward from 10 through 1. A pass or fail score was recorded because children found this task difficult: Children who successfully counted backwards without any error were coded as a pass, whereas children who failed to count backwards or made error(s) were coded as a failure.

Number identification. Children were asked to verbally identify two sets of Arabic numbers presented on cards from 1 through 20. They were first presented with the small set (i.e., 1 to 10 inclusive), followed by the large set (11 to 20 inclusive). Within each set, the order of the presentation was random. The testing was stopped (large set only) when the child failed to identify three consecutive numbers. Because the majority of children correctly named all of the digits in the small set, the score was the total named correctly for both sets. Internal reliability of the task was high for both sets (Cronbach's α = .88 for the small set and .89 for the large set).

KeyMath Numeration. Children's emerging numeracy skill was measured with the Numeration subtest from the Key Math Diagnostic Assessment (Form B, Connolly, 2000). The Numeration subtest includes questions about quantity, counting objects, ordinality, and place value, with increasing emphasis on the formal number system as the subtest progresses. Children were given the first 10 questions but the task was stopped if children made three errors in a row. Score was the total correct. Internal reliability of the task was acceptable (Cronbach's α = .74).

Nonsymbolic arithmetic. Children's ability to perform simple calculations on nonsymbolic problems was assessed based on the task created by Jordan, Huttenlocher and Levine (1992). There were three types of trials: matching (2 and 3), addition (1+2, and 3+1), and subtraction (3-1 and 4-2). For matching trials, the experimenter placed animals on her farm (a mat) and then hid them with a panel. The child was asked to copy the experimenter's farm with his or her animals. For addition and subtraction trials, the experimenter added or removed animals from her mat after the quantity was hidden. Then the experimenter asked the child to show her how many animals were in the farm now, using their own animals. For each trial, feedback was provided by showing how many animals were behind the panel. Score was the total correct. Internal reliability was calculated based on the sub-scores of first and second trials at each part, Cronbach's α = .64.

Spatial span. Children completed a Spatial Span Task that measured their spatial attention and working memory ability using an iPad application (http://hume.ca/ix/pathspan.html). On each trial, nine green dots were presented on the screen. Some of the dots lit up one by one. The children's task was to reproduce the sequence of dots in the same order by touching them. After a practice trial with two dots, trials were presented in sets of three (e.g., three trials with 2 dots, three trials with 3 dots). If they were incorrect on all three sequences, the task was terminated; otherwise, the next set of trials started. The maximum length of sequences was seven. Because most children only saw sequences up to four, internal reliability was calculated based on the sub-scores of first, second, and third sequences at each length (i.e., up to sequences of length four), Cronbach's α = .86.

Results

Chinese-Canadian children performed better than other Canadian children on all numeracy measures. As shown in table 1, the two groups differed significantly on number identification, nonsymbolic arithmetic, and Keymath Numeration. The groups were not significantly different on forward counting (see table 1) or backward counting. In both groups, fewer than half of the children successfully counted backwards from 10 (45% of the Chinese-Canadian children and 32% of the Canadian children), χ^2 (1, N = 94) = 1.62, p = .203, ϕ = .13.

Although the differences shown in table 1 support our prediction that the Chinese-Canadian children have more advanced numeracy skills than the other Canadian children, there were factors other than culture that might have contributed to these group differences. In particular, the Chinese parents had higher levels of education than the other parents. Chinese-Canadian children were also somewhat (although not significantly) more likely to be attending kindergarten: 40% of the Chinese-Canadian children were attending kindergarten compared to 32% of the Canadian children, χ^2 = (1, N = 94) = .74, p = .391. Furthermore, although mean ages were matched across groups, there was variability in the distributions. Age, kindergarten status, and mothers' education were all correlated with children's early numeracy performance. Thus, to examine whether the group differences were attributable to differences at home that were specific to the culture, we computed partial correlations between culture and the early numeracy measures, controlling for the children's age, mothers' education, and whether the children attended kindergarten. As shown in table 2, the partial correlation with culture remained significant for nonsymbolic arithmetic and for KeyMath Numeration. Notably, the numeracy measures that require mapping processes (i.e., forwards and backwards counting, number identification) were not different across the cultural groups. KeyMath Numeration and nonsymbolic arithmetic both require children to operate on numerical symbols and mental representations of quantities.

Performance on the Number Line Task

Number line performance was analyzed using *percent absolute error* (PAE), an index of how close children's placement of each number is to the actual location of that number, hence the precision of individual estimates. PAE was calculated as | (Estimate – Presented Number) / Scale of the Estimate| x 100. Thus, if a child marked the location of 7 at the position that corresponded to 6.5, the PAE would be 5% [| (6.5 – 7) / 10 | x 100)]. Other researchers have analyzed the percentage of variance (r^2) that is accounted for by the linear function to index linear fit (e.g., Laski & Siegler, 2007). However, r^2 tends to be highly skewed, because linear r^2 can be quite high as long as the child preserves the relative order of numbers, even if the estimates are not very accurate (LeFevre *et al.*, 2013). In a recent meta-analysis of number line performance, Schneider *et al.* (2018) showed that relations between the number line and other numeracy measures was similar across the different indices of performance. Accordingly, we focus on PAE because it directly shows the differences in performance to specific locations on the number line.

The mean PAE for each target number across conditions for each group was analyzed in a 2(group: Chinese-Canadian, Canadian) x 2(order: standard first, midpoint first) x 2 (condition: standard, midpoint) x 8(numbers: 1, 2, 3, 4, 6, 7, 8, 9) ANCOVA (see table 3), controlling for spatial span[2]. Children who were exposed to the standard number line first performed better than those who were exposed to the midpoint number line first (M_{PAE} = 22% vs. 26%). There was no interaction between order and any other variable.

Table 1. Performance differences between Chinese-Canadian and other Canadian children (N = 94)

Measures		Chinese-Canadians			Other Canadians			Group Comparisons				
	Max Score	M	SD	Range	M	SD	Range	Mean Difference	t (92)[1]	p	CIs	Cohen's d
Spatial Span	22	4.6	3.4	1-13	3.1	2.6	1-11	+1.5	2.34*	.022	[.3, 2.7]	.50
Forward Counting	100	40.4	36.8	5-100	26.7	26.9	5-100	+13.7	2.06	.043	[.5, 26.9]	.42
Number Identification	20	13.0	6.5	0-20	9.1	6.5	0-20	+3.9	2.84*	.005	[1.2, 6.6]	.58
KeyMath	10	5.0	2.2	0-10	3.4	2.4	0-10	+1.6	3.35*	.001	[.7, 2.5]	.69
Nonsymbolic Arithmetic	6	4.2	1.6	0-6	2.9	2.2	0-6	+1.3	3.31*	.001	[.5, 2.1]	.68
Number line[2] (Standard)	45.3	23.6	9.9	9-45	22.7	10.3	7-45	0.9	0.35	.726	[-4.6, 6.5]	.09
Number line[2](Midpoint)	54.3	15.8	11.0	4-45	22.3	12.1	4-54	-6.5	-2.08	.043	[-12.9, -.2]	.56

*Note. Bonferroni correction for multiple comparisons *p< .01.[1] Degrees of freedom were 91 for spatial span.[2] Percent absolute error*

Table 2. Partial correlations among early numeracy measures and culture, controlling for age (in months), kindergarten attendance, and mother's education

Measures	1	2	3	4	5	6	7	8
1. Culture								
2. Spatial Span	-.081							
3. Forward Counting	-.116	.198						
4. Backwards Counting	.066	.241*	.388**					
5. Number Identification	-.163	.040	.486**	.545**				
6. Nonsymbolic Arithmetic	-.270*	.203	.072	.013	.208			
7. KeyMath	-.253*	.409**	.444**	.406**	.581**	.391**		
8. Number line[1] (Standard)	.007	-.211	-.158	-.227*	-.217*	-.074	-.154	
9. Number line[1] (Midpoint)	.345**	-.139	-.130	-.169	-.280*	-.122	-.228*	.605**

*Note: * p< .05; ** p< .01[1]Percent absolute error. Culture was coded 1 = Chinese Canadian, 0 = other Canadian.*

Table 3. Summary of ANCOVA results for percent absolute error

Independent variables	df	F	η_p^2
Spatial Span (covariate)	1, 88	26.84***	.23
Order (midpoint condition first vs. second)	1, 88	5.42*	.06
Group (Chinese-Canadian vs. other Canadian)	1, 88	9.37**	.10
Condition (midpoint vs. no midpoint)	1, 88	19.33***	.18
Group x Condition	1, 88	13.13***	.13
Target (1, 2, 3, 4, 6, 7, 8, and 9)	7, 616	3.78**	.04
Target x Group	7, 616	1.95	.02
Target x Condition x Group	7, 616	.36	.004

** p< .05, ** p< .01, *** p< .001*

Consistent with their performance on the other numeracy measures, Chinese-Canadian children performed better than Canadian children on the number line task (M_{PAE} = 21% *vs.* 27%). Also as expected, children performed better in the midpoint condition than in the standard condition (M_{PAE}= 21% *vs.* 27%). Of most interest was the significant interaction between group and condition. Performance on the midpoint and standard conditions was not different for the Canadian children (M_{PAE} = 28% *vs.* 26%), p = .407, whereas the Chinese-Canadian children were more accurate in the midpoint than the standard condition (M_{PAE}= 16% vs. 25%), p< .001. This pattern is consistent with the prediction that children with better early numeracy knowledge would be most likely to benefit from the midpoint cue.

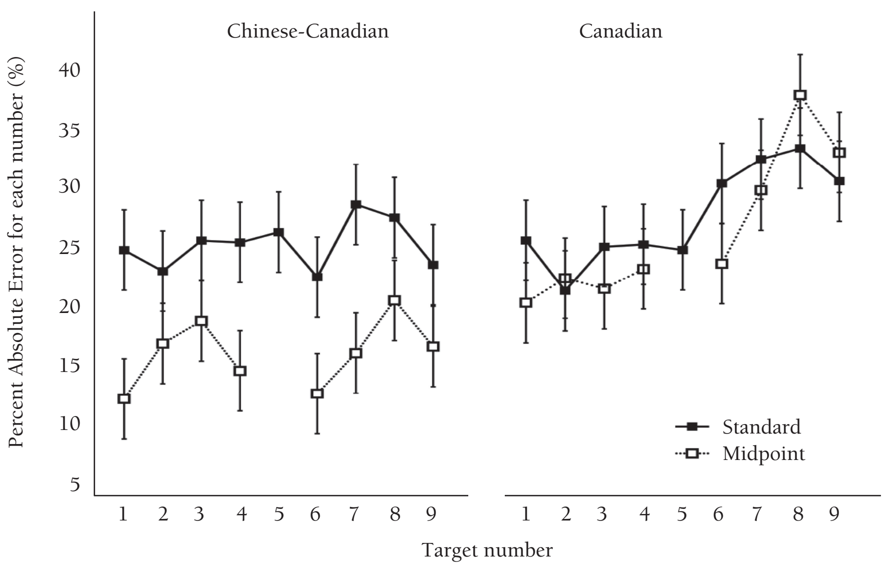
The main effect of target number was significant. Children were most accurate on number 1 (M_{PAE}= 21%) and least accurate on number 8 (M_{PAE}= 30%). The three-way interaction among group, condition, and target number was not statistically significant. As shown in figure 2, the Chinese-Canadian children showed less error on all of the numbers in the midpoint condition compared to the standard condition whereas the other Canadian children's performance was very similar across conditions for all numbers. Figure 2 does provide some suggestion of why the Chinese-Canadian children performed better in the midpoint condition. They had less error near the endpoints and the midpoint, specifically less error at 1 and 6 than at 3 and 8 in the midpoint condition. This pattern is consistent with the possibility that these children were using the midpoint to refine their estimates.

Summary. The midpoint reference helped the Chinese-Canadian children to keep their estimates closer to the actual locations of target numbers, particularly for numbers that are closer to the midpoint. In contrast, the Canadian children did not benefit from the midpoint reference.

Discussion

Chinese children typically show better performance on early numeracy tasks than children from Western countries (e.g., Miller, Smith, Zhou & Zhang, 1995; Siegler & Mu, 2008) and this advantage persists among the children of Chinese immigrants (e.g., Laski & Yu, 2014; Huntsinger *et al*., 1997). In the present study, we compared Canadian children whose parents had been educated in China to other Canadian children. As we predicted (Hypothesis 1), the Chinese-Canadian children showed an overall advantage on most numeracy measures; however, they did not perform better than the other children on the standard number line task. When provided with a midpoint reference for the number line, children were more accurate in their number line placements (Hypothesis 2); however, only the Chinese-Canadian children showed better number line performance in the midpoint conditions

FIGURE 2. Adjusted mean PAE for each number across conditions between groups, controlling for children's spatial span. Error bars represent 95% CIs calculated based on the MSEs from the 3-way interaction of group, condition, and target number (Masson & Loftus, 2003)



whereas the other Canadian children did not (Hypothesis 3).

Multiple factors were related to children's numeracy performance. Children attending kindergarten had more advanced skills, as did older children. Mothers' education was related to performance, and furthermore, the Chinese parents had received more education than the non-Chinese parents. However, even when mothers' education, children's kindergarten experience, and children's age were controlled, Chinese-Canadian children performed better on the numeracy tasks that involved quantities, arithmetic, or ordering, including the midpoint number line, the nonsymbolic arithmetic task, and the KeyMath Numeration task.

Why do the Chinese-Canadian children show an advantage on certain early numeracy skills? One possible explanation is that the Chinese-Canadian children had an advantage because they were tested in Chinese. Counting in Chinese is simpler than in many Western languages because the base-10 structure of the language is transparent in the verbal counting words: for example, 15 is the equivalent of *ten five* in Chinese (Chan, 2014). The transparency of the number language provides Chinese-speaking children with an advantage when they are learning to count (e.g., Miller *et al.*, 1995), but does not necessarily help them for other early numeracy tasks (Chan, 2014; Laski & Yu, 2014; LeFevre *et al.*, 2018). In the present research, most of the tasks for which the groups differed did not require knowledge of numbers greater than 10 (including the number line task) and thus differences in number language between Chinese and English are probably not contributing to differences in numeracy performance across groups (see also Laski & Yu, 2014).

What, specifically, was the source of the advantage for the Chinese-Canadian children on the number line? The number line task is unfamiliar to young children and quite difficult for them unless they have received training (Siegler & Ramani, 2008; Xu & LeFevre, 2016). However, presentation of an explicit midpoint reference supports young children's number line performance when they have an understanding of the sequential relations among numbers (e.g., what comes before and after number 5? Xu & LeFevre, 2016). The curvilinear pattern in the midpoint condition for the Chinese-Canadian children (see figure 2) was similar to the "M" pattern of performance identified by Ashcraft and Moore (2012) for older children on the 0 – 100 number line, which they interpreted as evidence that the children used an implicit midpoint. In the present research, the observed "M" pattern of performance in the midpoint condition suggests that Chinese-Canadian children used the midpoint reference to improve their solution strategy, for example, children might count from the midpoint to the target number for numbers closer to 5 (see Xu & LeFevre, 2016). In contrast, performance of Canadian children showed increasing error with number size for both the conditions and did not improve consistently in the midpoint condition, suggesting that they persisted in the strategy of counting from 0 (Pettito, 1990; Xu & LeFevre, 2016).

Several longitudinal studies have shown that mathematical performance as early as kindergarten or grade 1 predicts children's mathematical performance years later (Duncan *et al.*, 2007; Geary, 2011; Jordan *et al.*, 2009). Children's performance on early numeracy tasks before grade 1 is correlated with various aspects of their home environment, such as the frequency of direct parental instruction about numbers (e.g., counting and number identification) and indirect involvement in number-related activities (e.g., playing board games with dice; Dunst, Hamby, Wilkie & Dunst, 2017; LeFevre *et al.*, 2009; 2010; Skwarchuk, Sowinski & LeFevre, 2014). Compared to parents who were educated in Western countries, Chinese-educated parents engage in more home numeracy activities, have higher expectations with respect to mathematical achievement, and spend more time with their children focusing on mathematics than parents from other cultures (Aunio *et al*., 2008; Huntsinger *et al*., 1997; Pan, Gauvain, Liu & Cheng, 2006; Zhou *et al*., 2006). Thus, general differences in the home numeracy environment, leading to overall better performance at an earlier age, and/or specific differences in the activities provided by parents could be a source of the differences across groups in the present research. For example, Huntsinger *et al*. reported that Chinese-American parents spent over 50 minutes per day on mathematical activities whereas Euro-American parents spent only about 5 minutes per day on scheduled math activities. To the extent that differences between Chinese-Canadian and other Canadian children are linked to their home experiences, future research should explore specific home experiences in more detail. In the present research, we could not compare the home numeracy environments of the two groups because of the low response rate of the non-Chinese parents.

The differences in education level between the two groups of parents is also relevant in understanding why the two groups of children differed in number system knowledge. Parents with higher levels of education provide higher quality of instruction (e.g., more support in problem-solving situations), and are more involved in their children's educational attainment in the first year of school than parents with lower levels of education (e.g., Englund, Luckner, Whaley & Byron, 2004; Levine, Suriyakham, Rowe, Huttenlocher & Gunderson, 2010). These studies suggest that educational attainment is a relevant factor in comparing across cultures. Cross-cultural studies focusing on number line performance have not explicitly assessed parents' education levels as a potential difference between groups (e.g., Laski & Yu, 2014; Siegler & Mu, 2008; Muldoon *et al*., 2011). In future cross-cultural research, it is important to measure parents' education or other relevant demographic factors and to explore how those factors are related to children's performance across countries.

In conclusion, the present research showed that Chinese-Canadian children benefitted from the presence of a midpoint reference (e.g., marking the location of 5) when they were asked to locate numbers on a 0-10 number line. In contrast, other Canadian children did not benefit from the midpoint reference. The Chinese-Canadian children had more advanced early numeracy skills, specifically with respect to ordering and comparing numbers. These differences were probably not related to the children's formal educational experiences because the two groups attended similar daycares and schools in Canada. These results suggest that researchers should explore the role of parents in children's home numeracy experiences in order to understand the persistent advantages of East Asian children in early numeracy skills.

Notes

[1] An additional measure of the number line task was included using an iPad at the end of the session to explore if a new application for the task was appropriate for future research. The rapid naming task was also being piloted to determine whether it was suitable for young children. Results from these measures are not presented here but details can be obtained from the authors.

[2] Age and spatial span were highly correlated with each other so both could not be included as covariates. Furthermore, spatial span was significantly correlated with performance in the midpoint condition when age was not controlled (LeFevre *et al*., 2013).

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Resumen

Comparaciones interculturales del rendimiento numérico temprano de niños pequeños: Efectos de un punto medio explícito en el desempeño en recta numérica en niños canadienses y chino-canadienses

INTRODUCCIÓN. La capacidad de niños de colocar números en una línea donde solo los puntos finales están marcados está relacionada con otros aspectos de su comprensión matemática. En el presente trabajo hemos examinado los efectos de un punto medio de referencia (por ejemplo, marcando la ubicación del 5 en una recta numérica de 0-10) en el rendimiento de los niños pequeños (3 a 5 años) en una tarea de recta numérica. METODOLOGÍA. Hemos comparado niños con las mismas experiencias educacionales, pero con diferentes experiencias culturales: niños chinos-canadienses (*n* = 47) y niños canadienses cuyos padres fueron educados en Canadá o en otro lugar (*n* = 47). Todos los niños completaron una condición estándar con sólo los puntos finales marcados

y una condición de punto medio donde un punto medio de referencia fue presentado en la línea numérica. RESULTADOS. Las habilidades tempranas aritméticas de los niños chinos-canadienses fueron mejores que las de los otros niños canadienses. Los niños chinos-canadienses hicieron estimaciones más precisas de recta numérica cuando se proporcionó un punto medio de referencia en 5 comparados con niños canadienses, mientras que los grupos no difirieron en una recta numérica estándar (es decir, sin punto medio). Las diferencias culturales persistieron aún cuando la educación de las madres, la edad de los niños, y la asistencia a jardín infantil estuvieron controladas. DISCUSSION. Estos resultados sugieren que la mayor habilidad numérica básica está relacionada con el rendimiento de los niños en tareas nuevas y complejas, como la de una recta numérica. Estos resultados también indican que las diferencias entre grupos culturales diferentes pueden estar relacionadas con el idioma de instrucción, la educación de los padres, o diferencias en las actividades del hogar y enfatizan la importancia de desarrollar modelos más completos para interpretar las diferencias culturales en el rendimiento matemático.

Palabras clave: *recta numérica, punto medio, conceptos básicos de la aritmética tempranos, chino, canadiense, niños*

Résumé

Comparaisons interculturelles de la performance en matière de numérotation précoce des jeunes enfants: Effets d'un point médian explicite sur la performance de ligne numérique des enfants canadiens et sino-canadiens

INTRODUCTION. La capacité des enfants à placer des nombres sur une ligne, où seuls les bornes extrêmes sont marqués, est liée à d'autres aspects de leur compréhension mathématique. Dans la présente étude, nous avons examiné les effets d'une référence médiane (par exemple, marquer l'emplacement de 5 sur une ligne numérique 0-10) sur la performance des jeunes enfants de 3 à 5 ans sur une tâche de ligne numérique. **MÉTHODOLOGIE**. Nous avons comparé des enfants ayant des expériences éducatives similaires mais des antécédents culturels différents: enfants sino-canadiens (n = 47) et enfants canadiens dont les parents ont été éduqués au Canada ou ailleurs (n = 47). Tous les enfants ont effectué la tâche dans une condition standard avec seulement les bornes extrêmes marquées et une condition expérimentale où une référence au point médian a été présentée sur la ligne numérique. **RÉSULTATS**. Les premières compétences en numérotation des enfants sino-canadiens étaient meilleures que celles des autres enfants canadiens. Les enfants sino-canadiens, comparativement aux enfants canadiens, ont produit des estimations plus précises sur la ligne numérique lorsqu'une référence médiane à 5 a été donnée alors que les groupes ne différaient pas sur une ligne numérique standard (c.-à-d. pas de point médian). Les différences persistaient lorsque l'éducation des mères, l'âge des enfants et la fréquentation (yes/no) de l'école maternelle étaient contrôlés. **DISCUSSION**. Ces résultats suggèrent que de solides compétences en numérotation fondamentale sont liées à la performance des enfants sur des tâches nouvelles et complexes, telles que la ligne numérique. Ces résultats indiquent également que les différences entre les groupes culturels peuvent être liées à la langue d'enseignement, à l'éducation des parents ou aux différences dans les activités à domiciles et soulignent l'importance d'élaborer des cadres plus complets pour interpréter les différences culturelles dans la performance mathématique.

Mots clés: *ligne numérique, point médian, numérotation précoce, chinois, canadien, enfants.*

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