CARD GAMES:
A way to improve math skills through stimulating ANS.

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Teaching math at Primary school seems to be one of the most challenging things teachers have to do: most of the time children find it too difficult (Baroody & Dowker, 2003). Moreover, some recent work shows that children who are economically disadvantaged are particularly likely to experience difficulty in math (Sirin, 2005).

However, it is known that human beings (from newborns to adults) have a specific representational system that allows them to build amodal representations of the number of items or individuals in a given set (e.g., dots, light flashes, beeps and touches on the skin). This system is usually known as the Approximate Number System (ANS). It is thought to be an evolutionarily ancient system through which we are able to approximately represent quantity without the need for symbolic numbers or counting skills (Butterworth, 1999; Dehaene, 1997; Halberda, Mazzocco, & Feigenson, 2008).

The ANS represents quantity information in an imprecise manner on a 'mental number line', where smaller quantities are represented more precisely than larger quantities according to Weber's Law (Dehaene, 1997; Feigenson, Dehaene & Spelke, 2004). The Weber fraction can thus be understood as an index of ANS acuity (Dehaene, 1997).

Recently, de Hevia, Izard, Coubart, Spelke & Streri (2014) found that newborns just 48 –hours- old are capable of discriminating between 2 groups of dots. This piece of evidence strongly suggests that the ANS is innate (Xu & Spelke, 2000; Xu, Spelke & Goddard, 2005). Nevertheless, the precision of the ANS icreases with cognitive development, indicating some flexibility of this capacity (Halberda & Feigenson, 2008). Six-month-olds can discriminate numerosity in a 1:2 ratio (e.g. 8 vs 16 dots), and 10-month-olds can discriminate quantities in a 1:3 ratio.

Finally, there is a robust positive correlation between ANS acuity and symbolic math performance throughout development and into adulthood (Halberda, Mazzocco & Feigenson, 2008; Halberda et al., 2012). For example, ANS acuity at 6 months of age predicts symbolic number skills three years later (Starr, Libertus & Brannon, 2014; see also Jordan, Kaplan, Olah & Locuniak, 2006). There are also significant correlations between ANS acuity and school math achievement (Butterworth, 2010; Mussolini, Mejias & Noël, 2010; Mazzocco, Feigenson & Halberda, 2011). Furthermore, some recent work suggests that training ANS precision produces improvements in symbolic mathematics (Halberda and Odic, 2014), both in children (Hyde, Khanum & Spelke, 2014) and adults (Park & Brannon, 2013). These and other findings suggest that the ANS may be a cognitive foundation for symbolic mathematics (Dehaene, 1997; Feigenson et al., 2004; Gallistel & Gelman, 1992; Piazza, 2010).

These studies raise the question of whether ANS training should be implemented in schools. To date, however, there is no experimental evidence in school contexts to support such a change in educational policy. The present study addresses this issue by assessing the effect of a classroom card game on first grade students' ANS acuity and symbolic math performance.

METHOD

We used a two-phase cross-over design (Jones & Kenward, 1989) that included 3 assessments: one at the beginning of the study (baseline), one in the middle of the study (when one of the groups had already received the intervention while the other had not), and one at the end of the study (when the 2 groups had already received the intervention). After the baseline assessment (T1), one group was stimulated for three weeks with card games through regular class instruction while the other group had just regular classes (without any intervention). Then, all children were tested again (mid-study test, T2) and, after that, the intervention was implemented with the other group. Finally, after the second group received the intervention, all children were assessed again with a final test (T3).

Participants

Participants were 44 children attending first grade in a primary public school. Group A consisted in a class of 22 children, 10 of whom were girls (mean age = 6.77 years). Group B consisted in a class of 22 children, 12 of whom were girls (mean age = 6.63 years). Each class had its classroom and teacher.

Materials

Two different kinds of cards were used: Approximate Comparison cards and Addition cards (see Figure 1). All cards had two sides: one side with dots (blue and red) and another side with symbolic numbers corresponding to the quantities of dots. Cards were designed by Elizabeth Spelke's Lab at Harvard University, based on Justin Halberda's Panamath game (for more detail, visit: www.panamath.org).

Cards had different levels, levels were ratio dependent. Each level had four decks.

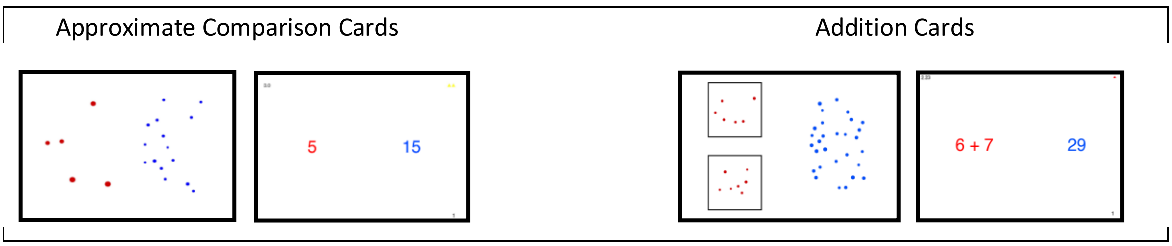

Figure 1: An example of approximate comparison cards and addition cards. Both games have 4 different difficulty levels. The difficulty level of each card is given by the ratio between blue and red dots.

Procedure

The study took place at school during class hours, five times a week. Each game session was 15 minutes long. The study started with the first evaluation (T1) of both groups (A and B). Then, during the first phase, group A played the card games and, after the second evaluation (T2), group B played the card games. Each phase of gaming lasted three weeks: in the first week, children played with approximate comparison cards, and in the second and third weeks children played with addition cards.

The game consisted of dividing the classes into four subgroups of 5 or 6 children. The subgroups played simultaneously. Every day, each subgroup had to play with two decks of the same difficulty level. The level of the cards was changed by two days, thus children had the opportunity to play with the four decks of each difficulty level.

Although the sessions were observed by one of the authors of this study, the regular teacher of the class was in charge of the activity and explained all aspects of the game to the children.

Assessments (T1, T2, T3)

At each testing point, a paper and pencil testing battery and a tablet evaluation battery were administered by one of the authors of this study.

Paper and pencil battery: Based on the work presented by Hyde et al. (2014), our team developed two assessments:

1. *Vocabulary test*. Sentence completion problem, composed by ten multiple choice sentences and read by one of the authors. Each sentence included a blank and three different word – options, only one of the options would serve to form a meaningful, complete sentence. Children had to choose an option. Accuracy was calculated after the testing session by assigning 1 point to each correct answer.

2. *Symbolic Addition test.* Composed of twenty additions. Children had to solve the additions, they could use any strategy or help: draw dots, count their fingers, etc. Accuracy was calculated after the testing session by assigning 1 point to each correct answer.

Tablet battery:

1. PUMA (Uruguayan Math Test). This is a math test for tablets that our team developed in 2013. PUMA is based on TEMA 3 (Ginsburg and Baroody, 2003) and has been used with 513 1st grade public school students in Montevideo (for more details about this project, see www.cognicionnumerica.psico.edu.uy/2013). For the present study, we chose 5 exercises from this math test. In exercise 1, children had to form the given number adding cards with different values: 1, 2, 5, 10, 20, 50, 100. In exercise 2, children had to add the value of the different cards given and choose the correct result from a list of three options. In exercise 3, children had to form a number given by using 10s. In exercise 4, children had to count dots and choose the correct number that correlate with that quantity from a number line. In exercise 5, children had to put in

order number from 1 to 10 but beginning from the 10 and ending by the 1 (decrease order number line).

2. PANAMATH (www.panamath.org, Halberda et al., 2008). This is a computer game developed to measure children´s approximate numerical acuity. In this task, children see a set of yellow dots (right side) and a set of blue dots (left side) simultaneously on a tablet screen. Children have to indicate the array that has more dots by tapping the correct panel.

RESULTS

Children performed numerically better on the symbolic addition test (Figure 1) and the short version of the PUMA Test (Figure 2) after playing the comparison and addition cards games. Furthermore, group A's performance showed an improvement even after the intervention had finished. Although this pattern of results is encouraging, none of these differences were statistically significant due to the small sample sizes.

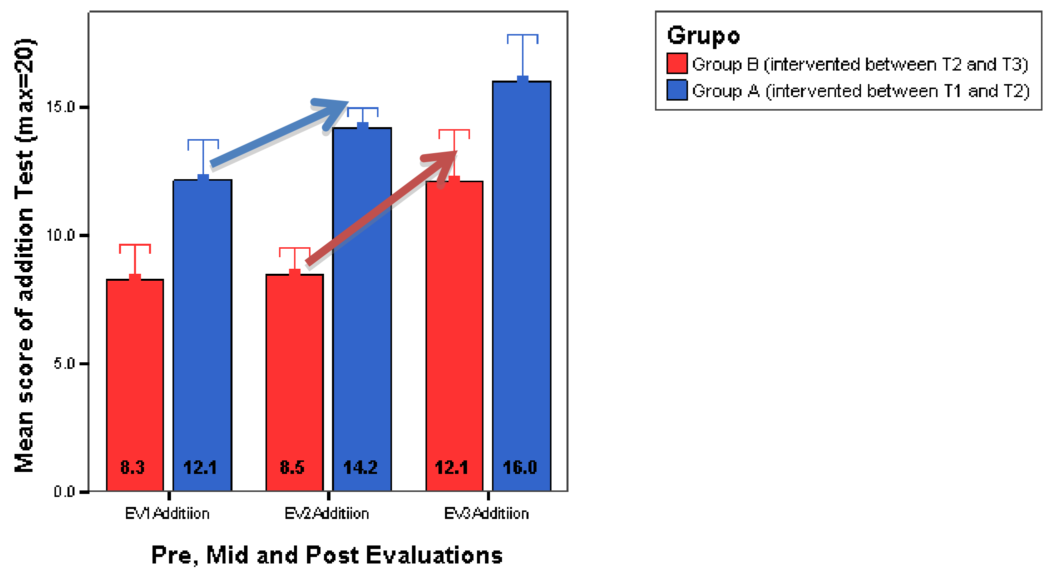

Figure 1: Mean scores of symbolic addition test for both groups at the 3 testing points. Group A (Blue bars) received the intervention first and group B (red bars) received the intervention after the second evaluation point (T2). The arrows show the increase in performance for each group from the test just before the intervention to the test just after the intervention.

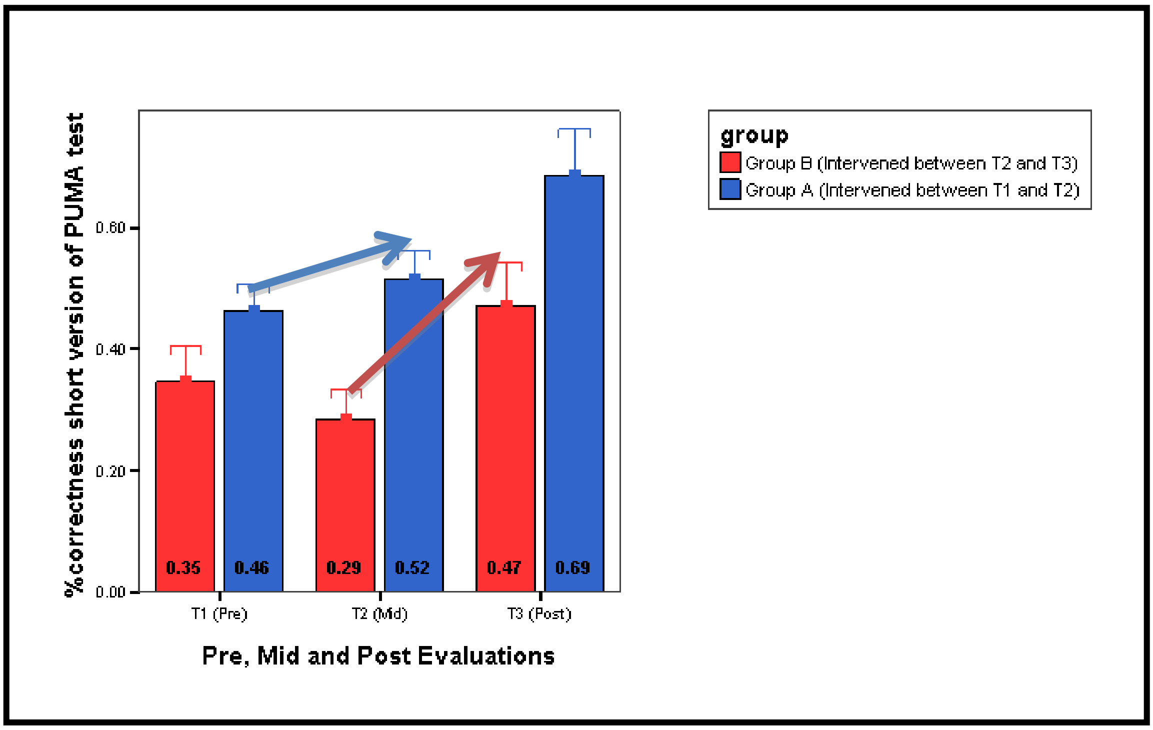

Figure 2: Percentage of correctness in the short version of the PUMA test. Group A (Blue bars) received the intervention first and group B (red bars) received the intervention after the second evaluation point (T2). The arrows show the increase in performance for each group from the test just before the intervention to the test just after the intervention.

It is also important to note that teachers of both groups A and B reported that children displayed more positive attitudes towards math after playing the card games.

DISCUSSION

We found an improvement in symbolic math (paper-and-pencil addition test and computer-based PUMA test) that seems to come from the training program using with the card games described above. However, it is important to highlight that the benefits may be greater for children who are not very good at math: group B performed worse than group A at T1, and seemed to benefit more from the intervention.

We also found an improvement three weeks after the intervention finished (for group A). It is possible that this indicates a carry-over effect of the training program, or an improvement due solely to increased motivation after the training program. Further work is needed to address this particular issue, and most importantly, to confirm the robustness of these results with larger sample sizes.

We believe that our findings suggest an intriguing benefit to math learning from an easily implemented classroom card game. It may be that such games are especially important during the early years of schooling, as early childhood math ability predicts a variety of learning outcomes in adolescence (Duncan et al., 2007).

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