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Children with Down Syndrome and Relative Quantity

Can Children with Down Syndrome Judge Relative Quantity?

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Abstract

Children with Down syndrome (DS) can experience a number of difficulties in mathematics but one relatively unexplored area is that of being able to discriminate between quantities; an important foundational skill for later learning. This study examines whether children with DS can make judgments about relative quantity in the context of a card game with two groups of children group 1 (N=16) mean age 8y 2m and group 2 (N=27) mean age 14y 3m. The data reveal that they were able to make judgements when the ratio between quantities varied as little as 3:4; for the younger children small set sizes proved to be harder than large sets raising a number of implications for teaching. In both groups there were children who performed at chance level across all set sizes, suggesting that some children experience specific difficulties, but these did not necessarily impede attainments in mathematics.

Key Words: Down syndrome: relative quantity; subitizing, mathematics

Background

Mathematics is considered to be an area of particular difficulty for children with Down Syndrome (Buckley 2007; Faragher & Clarke 2014) and is still considered “largely unchartered territory” (Faragher, Brady, Clarke & Gervasoni, 2008 p10). There is however a small but growing body of evidence that specifically tailored interventions, ones that capitalize on children’s visual abilities and limit the demands on working memory, can lead to the successful acquisition of: addition and subtraction (Herrera, Abruno, Gonzalez, Moreno & Sanabria, 2010, Agheana & Duta 2015); place value (Gaunt, Moni & Jobling, 2012); fractions and percentages (Martinez & Pellegrini 2010), but with notable individual differences and with some areas continuing to pose a challenge (Lanfranchi, Berteletti, Torrisis, Vianello & Zorzi, 2015). This produces a complex picture for while some children with Down syndrome (DS) are achieving others are not, leading some researchers to hypothesize the presence of dyscalculia (Cuskelly & Faragher 2019). One particular area of potential difficulty is counting where a significant proportion of children with DS fail to acquire the underlying principles (Porter 1999; Abdelhameed 2007). Children face challenges in the skills of counting, making errors producing the list of count words whilst tagging each and every object with one (and only one) count word. Consequently they are delayed in knowing that the last tag word signifies the number of objects (cardinal errors) (Porter 1999; Nye, Fluck & Buckley, 2001; Abdelhameed 2009 ; Charitaki, Baralis, Polychronopoulou, & Soulis, 2014). These difficulties have led some to conclude that too much emphasis is placed on teaching counting (Clarke and Faragher 2014) and that other approaches, including those based on subitizing (Tuset, Bruno & Noda 2019) are needed.

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This paper focuses on the ability to mentally represent quantity, a skill that usually occurs before the acquisition of speech and is said to provide a foundation for later mathematical learning. Empirical studies with neurotypical children have suggested a link between individual differences in children's ability to perform on these non-symbolic number comparisons tasks and attainments in early arithmetic (Fazio, Bailey, Thompson & Siegler, 2014; Wang, Odic, halberd, & Feigenson, 2016; Peng, Yang, & Meng, 2017). This raises the possibility that if we can foster this ability to discriminate between quantities then we provide children with a stronger platform for later learning (Wilson, Dehaene, Dubois & Fayol, 2009; Obersteiner, Reiss & Ufer, 2013; Hyde, Khanum & Spelke, 2014; Van Herwegen, Costa, Nicolson & Donlan, 2018). In this context there has been considerable interest in these abilities as a possible root of mathematical difficulties in children with particular genetic conditions (see Allman, Pelphrey & Meck, 2012 for a review of these). This article considers what we know about the development of these early skills in children with DS. It presents data collected as part of a wider study to examine the extent to which children with DS can make judgments about *relative* quantity when the conditions for responding are set within the motivating context of a game.

Awareness of Magnitude

Studies with neurotypical children suggest that an awareness of numerical properties develops from infancy. Very young infants have been found to discriminate between arrays of 1, 2 and 3 dots, puppet jumps and objects (Starkey and Cooper 1980; Strauss and Curtis 1981; Wynn 1996). Moreover infants have been found to predict the outcome of additions and subtraction involving quantities of 1,2 and 3, (Wynn 1992; Fiegenson, Carey and Hauser 2002). Typically however young children fail on all these tasks when the quantities involved are 4.

However children of a similarly young age are also able to distinguish between arrays using large set sizes when they differ in the ratio of 1:2 (Xu and Spelke 2000; Brannon, Abbott, & Lutz, 2004), for example, infants at six months can discriminate between arrays of 8 and 16 (but not 8 and 12). By nine months typically developing infants can discriminate between quantities presented in ratios of 2:3; and 3:4 at three years; 5:6 at six years (Halberda and Feigenson 2008: Siegler & Lortie-Forgues 2014). The significant aspect of these studies is that *ratio* rather than absolute number determines children's abilities.

Researchers have argued that at least in the preschool years, different cognitive systems underpin the response to tasks involving small sets and those involving larger sets. Fiegenson and colleagues have argued that infants mentally represent (and track) objects individually, opening a mental object file for each item. This object tracking system is precise but limited in capacity to representing 3 items in children (4 in adults) (Feigenson, Dehaene, &, 2004) and lends itself to the possibility of mapping on a number label (Ansari and Karmiloff-Smith 2002; vanMarle, Chu, Mou, Seok Rouder & Geary 2016). It is however sensitive to differences in surface area (Xu 2003). Researchers have also demonstrated how awareness of small quantities informs motor responses and problem solving behaviours (Feigenson & Carey 2003; 2005) illustrating the wider utility of this ability.

Researchers argue for the presence of a second system for mentally representing larger sets referred to as an approximate number system (ANS). As we have seen this enables young children to discriminate between quantities that are increasingly similar and here it is the distance between the quantities (i.e. ratio) rather than absolute number that determines the ease with which they achieve this. Notably however the mental representations are imprecise

(Sella, Berteletti, Lucangeli & Zorzi, 2016). With larger sets, even in infancy, numerosity rather than surface area or contours appears to be the discriminatory variable (Cordes & Brannon 2009; Libertus, Starr, & Brannon 2014). In addition to supporting the approximate representation of quantity, it is argued to support transformations in those representations in relation to ordinal relationships, arithmetical operations of addition and subtraction and reasoning about proportions, (Szkudlarek & Brannon 2017).

A series of meta-analyses suggest that there is a modest correlation between ANS acuity and maths achievement (Chen and Li 2014) but the contribution of the ANS is strongest in the pre-school years (Fazio et al 2014; Schneider et al 2017) and that this has been found to be particularly true for low attaining children. (Bonny & Lourenco 2013; Purpura & Logan 2015; Szkudlarek & Brannon 2018). This suggests that the acuity of the ANS is an important line of enquiry for children with Down syndrome, many of whom are likely to be functioning in maths at a level equivalent to pre-school children (Porter 1998) and who have been found to have a specific difficulty with cardinality (Nye et al 2001; Abdelhameed 2009).

Children with DS and Discrimination of Quantity

Previous studies have largely sought to discover whether children with DS experience particular difficulties in discriminating between quantities or if their development is simply delayed. Early studies suggested that young children with DS experienced difficulties discriminating between arrays of 2 and 3 based on their responses to habituation tasks (Paterson 2001). This is consistent with the finding of Camos (2009) that between the ages of 4-8 years children with DS could discriminate between 8 and 16 but not between 8 and 12, although their profile was not significantly different to their matched MA control group. Participants with a wider age range in a study by Abreu-Mendoza & Arias-Trejo (2015) appear to show a stronger profile. They found that children with DS aged 3-22 years performed above chance on all four ratios 1:3; 1:2, 2:3 and 3:4 using large number sets when asked “where is there more,” performing similarly to a matched MA control group. Their participants with DS followed the developmental pathway of decreasing ability as the ratio decreased. Belacchi et al (2014) included a similar task of indicating which is more using large sets but found conversely that their participants (aged 15-29) did significantly worse to a matched MA control group. They did as well however on a task requiring them to add approximate numbers. Sella et al (2013) also found that compared to MA matched controls, her group of participants with DS (mean age 14 years) performed worse on ratios 2:3 and 3:4 in tasks requiring the discrimination of “same or different” using both large and small set sizes. Zimpel and Rieckmann (2020) in a large scale study involving participants with good counting skills found while their group with DS were able to correctly identify conventional dice pattern were unable to estimate numbers of 4 of more items in a variety of different arrays, unlike their neurotypical groups. There is therefore a mixed picture as to whether children and young people with DS are simply delayed in their acquisition or experience particular difficulties.

Researchers have also looked to explain differences in performance through considering set size. It has been argued that discrepancies between performance on small and large sets with the same ratio depend on the underlying strength of the object tracking system, for small sets using quantities under 4; or on the ANS, for sets larger than 4. Thus Camos (2009) argued that the success of her participants on her large set size task lay with the relative strength of the ANS and is consistent with the findings of Abreu-Mendoza & Arias-Trejo (2015), but not those of Belacchi and colleagues. Sella et al (2013) suggest that poor performance of their participants was due to the functioning of the object tracking system as performance of the children was poor in the subitizing range and they revealed a ratio dependent effect as if they were relying on the ANS. Sella et al (2013) did not provide an equivalent ratio in comparing performance on large and small set sizes. Paterson (2001) used small set sizes but a rather different methodology, yet one analysis of her findings is that children failed to discriminate due to a poor object tracking system. This is consistent with the conclusions of Zimpel and Rieckmann (2020) who argue for a particular attentional difficulty.

In summary, three studies have suggested that young people with DS experience difficulties with small number presentations that have been argued to rely on the object tracking system (Paterson et al 2006; Sella 2013; Zimpel and Rieckmann 2020) but research suggests that the ANS appears to be relatively preserved as they demonstrate a ratio effect with larger set sizes. No studies however have compared performance on identical ratios using large and small set sizes. If we can locate the particular challenges we are in a better position to understand how best to support the learner. Through comparing judgments of quantity within and beyond the subitizing range we can investigate the role of the object tracking system, and through establishing whether there is a ratio dependent effect we can establish the functioning of the ANS.

Procedures used in the following study were designed to optimize children's performance. It utilized a game, conducted in a familiar setting (rather than a lab) deploying strategies of anticipation, intonation and reward to keep participants engaged. The pace of the game was determined by the speed of participants' responses and stopped as children overtly lost interest (i.e. moved away or indicated they did not want to play anymore). These data form part of a larger study designed to examine children's responses to developing an iPad game, the details of which are reported elsewhere (Author 2018). The card game was used as a standard comparator across two groups of children, reported separately here as the context for recruiting the children and the availability of time slots placed different constraints on the accompanying data. However it provided a unique opportunity to consider the following questions:

Can children with DS make judgments about *relative* number?
Do children with DS perform better with small or large set sizes? Do these reveal a ratio dependent effect?

Methods

Participants and Setting

Two groups of children with DS were recruited. Sixteen children (11 boys and 5 girls) in group 1 ranged in age from 3 years 8 months to 12 years 6 months (mean 8y 2m, S.D. 33.4m). Twenty-seven children (13 boys and 14 girls) in group 2 ranged in age from 9years 6 months to 19 years (mean 14 years 3 months S.D. 32.1m). For the first group, parents were approached via a DS organization that forwarded information and an invitation to their members. Children in group 1 largely attended mainstream schools or nursery and were, on average, younger than group 2. The second group was approached via two special schools where parents also received information and consent forms for their child to take part. Ethical procedures followed University guidelines for formal approval. Following parental consent children were approached with information about the project and invited to take part. For both groups children were accompanied by a familiar adult, (parent or teaching assistant), unless they expressed a desire to take part without. Sessions took place in a quiet room in either the centre (in the case of the voluntary organization) or school.

Procedures

The card game involved the presentation of a series of pairs of playing cards. On each of these was a random array of dots with each pair containing dots of the same colour and size. Each pair in turn was placed face up in front of the child who was invited to pick the one that has “more dots” with no counting. They then turned over the chosen card to see if it had a golden star on the back, indicating a correct choice. They kept the pair if they were successful. Children were given a demonstration and practice trial using ratio 1:3 prior to completing the game. The card pairs contained either small or large sets of dots of the following ratios: 1:3 (1:3, 3:9); 1:2 (1:2, 4:8); 2:3 (2:3, 4:6); 3:4 (3:4, 6:8); and 5:6 (5:6, 10:12). Children in group 1 played the card game across 2 sessions and group 2 completed their trials within 1 session. The order of small and large sets was alternated across games. Following the presentation of the digital and card game, ten of the children in group 1 also completed the British Picture Vocabulary Scale long form (Dunn, and Dunn, 2009) scoring 25-69 months [mean 47.5, S.D. 13.82m]. For group 2 data was collected from their teacher on their level of attainment in the mathematics national curriculum.

Data analysis

Data on the percentage of correct trials were analyzed using SPSS version 21 to provide descriptive statistics, and explore skewness and kurtosis, which indicated that the data were not normally distributed and the need for non-parametric statistics: Friedman ANOVA was used to compare performance across ratios; Kendall Tau to examine the relationship between task performance and chronological and mental age; Wilcoxon signed-rank tests were used to compare differences between children’s performance on small and large set sizes. Bootstrapping was employed to offset bias arising from small sample sizes (Field 2017)

Results

Group 1

As table 2 reveals between two-thirds and three quarters of the responses were correct in identifying which is "more" when presented with two quantities varying in the ratio 1:3; 1:2; 2:3; and 3:4. This figure drops to 57% when the ratio was 5:6. Children's performances did not follow the expected pattern of responding with performance on ratio 3:4 higher than 2:3 as revealed in figure1. There was a non-significant difference between performances on the 5 ratios, $\chi^2_{[4]} = 4.259$, p=0.1372. There was a significant difference for discrimination between small and large set sizes, comparing performance on sets of 1:3 and 3:9; 1:2 and 4:8; 2:3 and 4:6, T=68, p=. 022 with a medium effect size, r= .40. As a group the children performed better when presented with the ratios using larger numbers of dots (mean 83% correct; median 100%) compared to small (mean 67% correct; median 66%).

Insert table 1 here

There was no significant correlation between chronological age and children's overall performance on the cards for group1, (τ = .09 p=.324). Similarly there was no significant correlation between chronological age and performance on small sets, (τ =.01 p= .48) or large sets (τ = -.12 p=.28). There was also no significant correlation between task performance and mental age for the 10 children for whom we had BPVS scores, (τ =.24 p=.18). In order to further understand variation within the group, the number of children performing at three different levels was examined. This was prompted by observing in the larger study, how mainstream children who played the digital game could sometimes get distracted from near perfect scores. We therefore made a distinction between those who responded with 100% correct across all trials; those who "can do" in that they perform well above chance, scoring 70% or higher; and those whose performance is around the level of chance. Two particular elements are notable in these data in table 2. Firstly, almost two thirds of the children responded to ratio 1:3 with 100% correct, demonstrating they understood the task requirements. Secondly, most responded to the ratio 5:6 randomly- it was too hard most of this group. In order to examine the relationship between performance of these three groups and how they performed on each of the ratios we used an exact test of the distribution (*rxc* Exact Contingency) This indicated that there was a significant difference in performance p=.007.

Insert table 2 here

Group 2

Children's performance as a group was considered first to examine responses across four ratio conditions (1:3 was only presented for demonstration and practice). As table 4 reveals 86% of the group responses were correct on the easiest ratio of 1:2 and this dropped away to 66% when the ratio was 5:6.

Insert table 3 here

Children's scores in group 2 mirrored the developmental pattern as the percentage of correct responses decreased as the ratio between quantities got smaller, (see figure 2). There was a significant difference between performances on the 4 ratios, $\chi^2_{[3]} = – 13.25$, p=.004. Wilcoxon tests were used to follow up the findings and compare performance on specific pairs of ratios revealing significant differences in performance on ratio 1:2 and 5:6, T=11, r=-

.34 *p*=.016, and performance on 2:3 and 5:6, *T*= 57, *r*=.31 *p*=.032. Other ratio combinations proved not significant, (1:2 and 2:3, *T*= 14.5, *r*= .28 *p*=.184; 1:2 and 3:4 *T*=22, *r*= .23, *p*=.099; 2:3 and 3:4, *T*=71. *r*=-.25 *p*=.074, 3:4 and 5:6, *T*=58, *r*=.22 *p*=.136).

Insert figure 2 here

With this larger sample of children in group 2, chronological age was significantly correlated to performance on cards, τ= .339 *p*=.009 (1 tailed), [95% confidence interval, .049-.617].

In order to understand variation within the group, the number of children performing at the three different levels were again examined (see table 4) to reveal that 22 of the 27 scored over 70% and 5 (20%) children were random responders on the easiest level. Fifteen children who attempted the hardest level with ratios of 5:6 scored 70% or more. This older group was more successful on the task with 11 children performing at ceiling level. Given this skewing it was not surprising to find no significant relationship between the groups and performance on each of the ratios. An *r x c* exact test of distribution was non-significant p=0.27.

Insert table 4 here

Mathematics attainment data were available for all 27 pupils (see table 5). This places 7 pupils as working towards Level 1 of the national curriculum, that is below the level of a typically developing 5 year old, ranging from pre level 5 (the lowest) to pre level 8 (the highest); 11 pupils were at Level 1, (usually achieved by pupils aged 5 years); 5 were at level 2, (usually achieved at ages 6-7); and 1 pupil was working at level 4, (usually achieved at age 10). Additionally 3 pupils were working on the National Qualifications Framework for Adults, 1 at Entry level 1, equivalent to applying the skills acquired at age 5-7 years, and 2 were working at Entry level 2, applying maths skills equivalent to age 7-9 years.

Insert table 5 here

The pupils therefore spanned a range of mathematics achievement. Further, within each level of maths attainment were children who performed quite differently on the card task. For example, the 11 children working at level 1 (equivalent to age 5 years) ranged from performing at the level of chance, to being able to compare sets in the ratio of 5:6. The two children working at the lowest level (pre level 5) were not responsive to the card game. Conversely, the pupil working at level 4 of the curriculum (equivalent to age 10 years) was consistently able to discriminate ratios of 5:6. Two pupils, attaining at Level 1 of the National Curriculum, equivalent to a 5 year old yet performed below chance for all ratios. A further pupil's performance was also surprising, given that they were attaining at Entry level 2 (age 7-9 years) but only able to complete the easiest ratio of 1:2. These pupils appeared to be responding below expectations given their mathematics achievements.

Discussion

In answer to the question: Can children with DS make judgments about relative number? The group data from this study suggest that children with DS can make these judgments, but with considerable variation in performance. Older children performed, on average, better than younger, consistent with the findings of Paterson et al (2006) and Abreu-Mendoza and Arias-Trejo (2015). Taking group averages, between two thirds and three-quarters of responses in group 1 were correct for all ratios except 5:6. Overall, group 2 were more competent with 6 a larger number of the older group performed with 100% correct across all ratios and 66% of group responses correct on the hardest ratio of 5:6. However, the data also reveal that a proportion of the children in both groups could best be described as random responders with 4/16 (25%) in group 1 and 5/27 (19%) children in group 2 unable to make judgments of quantities that varied in the ratio of 1:2.

The older group demonstrated a pattern consistent with those of neurotypical children with mean correct responses decreasing with decreasing ratios and chronological age proved to be a significant predictor. Group 1 averages did not however entirely mirror the expected slope of decreasing ratio and decreasing performance. This could be explained by a significant difference in their performance on small and large set sizes, most notably for comparisons between 1 and 2 dots. Children performed better with larger set sizes. Arrangements for testing precluded this analysis for group 2. We can however reflect on group 2's mathematical attainment. There were surprises in both directions. Children performing below the curricular level expected at age 5 years (p7 and 8) were able to judge quantities that varied in the ratio of 5:6. Equally two children at level 1 (equivalent age 5 years) performed below chance. Informal observation suggested that they adopted a non-functional strategy, always choosing the item on one side.

Group1's poor performance with small number sets is consistent with the findings of Paterson et al (2006) and Sella et al (2013) which these authors suggest are due to difficulty with the object tracking system. This could be indicative of the demands on visual attention and memory that come with a deeper layer of processing for object tracking rather than the quicker perceptual processes required for judging large number sets. Children with DS are often described as having strong visual processing skills but not all visual-spatial skills are superior. Brodeur et al (2013) report children's difficulty in tracking more than a single object, and the random presentations of dots may have presented a difficult context. Mou and vanMarhle (2014) argue that items that are easily individuated are easier to attend to and that contrasting features between items are more likely to prompt separate representations. Small arrays of dots may therefore be particularly problematic. This finding is also consistent with Zimpel and (2020) argument for an attentional difficulty that is not specific to number tasks.

An equally possible account lies with interference, as children in our study failed on sets of 1, 2 and 3. Small sets are more likely to have acquired a number label (than large ones) and can make the request for "which is more" nonsensical, when for example it already has a label of "two". This would be particularly problematic for younger children in the early stages of acquisition. The inclination of our case study children in the face of confusion was to adopt a locational strategy for choice, effectively removing the attentional demands of the task, a strategy that mirrors that described by Wishart (2001) as the erosion of "motivation to engage fully in learning" p48. These alternative explanations for poor performance need testing out as they have important implications for the teacher if promoting a pattern- label response inhibits an understanding of the *relative* properties of number. The use of structured fixed patterns materials, (such as those on dice) are a common pedagogic tool for teaching children with Down syndrome but these resources don't necessarily mimic quantity in the wider environment and require supplementing (Wing and Tacon 2007). Tuset et al (2019) also note superior performance when items used a binary arrangement.

Our findings with group 2 were that the majority of children are largely successful with this task, and with a clear ratio effect suggesting the deployment of ANS. This contrast to the largely younger group and is consistent with the argument that the relationship between the ANS changes over time with the introduction of formal schooling (Szkudlarek & Brannon

2018). A positive finding of the study was that some of our participants in group 2 had progressed in mathematics despite performing poorly on the card task with the implication that in the main this need not impede more general mathematical progress.

The presence of a small group of random responders, in both groups, could be indicative of a level of co-morbidity between Down syndrome and developmental dyscalculia. Cuskelly and Faragher (2019) suggest that the difficulties in arithmetic experienced by children with DS match those of children with dyscalculia. However our data also indicates that poor performance in making judgments of relative quantity was not inevitably linked to poor progress in mathematics, as can be seen for child 13 and 15 in table 5, but equally good performance in making these judgments did not automatically link to better attainment in mathematics (child 5 and 7).

The data from this study contributes to our understanding of the performance of children with DS on a relative quantity task. As with much research in this area, a limitation lies with the size of the participant groups, especially group 1, coupled with the lack of opportunity to collect exactly comparable data with both groups. In part this resulted from the recruitment strategy, initially approaching a DS voluntary organization, and then, to ensure a broader range of children with DS, special schools. While this was an efficient strategy for improving the representativeness of the group it made for differences in the availability of additional attainment data.

A second area of potential limitation lies with drawing on previous published studies with typically developing children to provide a commentary on the profile of attainments rather than incorporating our own comparison group. Matching is always a complex issue given the disparity in the age range of the group with concomitant differences in their experiences (Mervis & Klein-Tasman 2004; King, Powell, Lemons, and Davidson 2017), making the notion of equivalence problematic.

Despite the limitations of this study, it does raise important questions. How have children with DS achieved in mathematics without being able to make judgments of relative quantity? And conversely, why do some children show proficiency in making these judgments but their attainments in mathematics are low? These questions run counter to the research with other low maths attaining children that suggest that supporting the development of the approximate number system will benefit children’s understanding of cardinality and contribute to mathematical achievements. Further in-depth longitudinal data is required tracking individual responses to intervention over time, to understand the nuances of this relationship. The literature suggests that children can be introduced to tasks that require discrimination between quantities before they have knowledge of count words. Our findings suggest the intervention initially uses large sets of items (greater than 4) rather than small, with ratio between quantities an important factor in task difficulty. It is timely for future research to more formally evaluate intervention in this area for children with DS including those who experience particular difficulty.

Conclusion

Empirical studies of children with DS face many difficulties. Adopting a game based approach to relative judgments of quantity, this research has suggested a complex picture, with two- thirds or more correct responses by the older group to ratios of 1:2; 2:3; 3:4 and 5:6 but with a more varied picture amongst the younger group where over a third of the group responded randomly even to the easiest ratios of 1:3. These findings reinforce the importance of looking at within group differences. The younger children found it more difficult to make judgments of quantity with small sets than large. This finding is consistent with that of Paterson et al (2006); Camos (2009) and Sella et al (2013) but unlike previous studies has the advantage of directly comparing performance with the same ratio when using quantities within the subitizing range with those that exceed it. A variety of hypotheses were explored about the nature of the difficulty, including the possibility of interference through small sets having acquired a label making the request for “more” nonsensical. This needs further investigation as it has important implications for teaching.

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Card Ratio	**Mean % Correct Responses**	**S.D**	**95% Confidence intervals**	**No of children completing the task**
1:3	**79.41**	**30.92**	**15.90**	**17**
1:2	**72.29**	**31.82**	**16.36**	**17**
2:3	**67.59**	**35.61**	**18.31**	**17**
3:4	**73.33**	**41.69**	**23.09**	**15**
5:6	**53.57**	**45.84**	**26.47**	**14**

Table 1: Performance of Group 1 on the card game

Card Ratio	Numbers of Children who were 100% Correct	Numbers of Children who were 70%+ Correct	Numbers of Children who made random responses	Total
1:3	11 (65%)	0	6	17
1:2	4 (24 %)	9	4	17
2:3	7 (41%)	4	6	17
3:4	7 (47%)	3	5	15
5:6	3 (21%)	1	10	14

Table 2: Individual responses of group 1 to the card game

Card Ratios	mean % correct responses	S.D	95% CI	Number of Children
1:2	80.37	31.84	11.89	30
2:3	75.90	33.82	12.63	30
3:4	72.46	34.30	13.30	28
5:6	67.12	37.26	15.05	26

Table 3 **Performance of Group 2 on the card game**

Card Ratio	Numbers of Children who were 100% Correct	Numbers of Children who were 70%+ Correct	Numbers of Children who made random responses	Total
1:2	20 (67%)	4	6	30
2:3	17 (57%)	5	8	30
3:4	12 (46%)	7	7	26
5:6	11 (42%)	6	9	26

Table 4. Individual responses of group 2 to the card game.

	CA in months	Best Ratio Cards (70% + Correct)	Maths Level
1	117	Not engaged	P5
2	128	Not engaged	P5
3	131	2:3	P6
4	147	1:2	P7
5	187	5:6	P7
6	96	All at level of chance	P8
7	150	5:6	P8
8	171	3:4	P8
9	132	5:6	1
10	132	5:6	1
11	149	2:3	1
12	153	5:6	1
13	156	All at level of chance	1
14	165	3:4	1
15	170	All at level of chance	1
16	171	2:3	1
17	171	3:4	1
18	178	2:3	1
19	215	5:6	1
20	174	2:3	2
21	190	5:6	2
22	193	5:6	2
23	198	5:6	2
24	202	5:6	2
25	190	3:4	Entry 1
26	221	1:2	Entry 2
27	228	5:6	Entry 2
28	227	5:6	4

Table 5 Mathematics attainment levels and children’s highest performance on the card game