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The robustness of preschool children's tendency to count discrete physical objects.

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The robustness of preschool children's tendency to count discrete physical objects.

Abstract

When pre-school children count an array of objects containing one that is broken in half, most count the halves as two separate objects (Shipley & Shepperson 1990). Two studies explore this predisposition to count discrete physical objects (DPOs) and investigate its robustness in the face of various manipulations. In Experiment 1, 32 children aged 3–4 years counted arrays of intact and broken objects, comprising familiar objects known to be separable (e.g., a lolly and its stick) or non-separable (e.g., a toothbrush). The meaning of presenting a broken object was made explicit as some children saw a 'naughty teddy' cause the breakage. The DPO bias was robust in the face of these familiarity and context manipulations. Experiment 2 tested whether the DPO bias could be overcome by teaching children a strategy for counting two parts as one whole and also considered whether children's prior knowledge of cardinality was associated with the bias. Only 8 children (33%) benefited from the strategy teaching. At a second post-test 2–3 days later, half of these had reverted to their DPO bias. . Cardinality knowledge was not associated with improvement. The robustness of the bias to count DPOs is discussed in terms of innate predispositions and abstracted representations.

Introduction

When pre-school children are asked to count an array that includes one broken object, they count the two parts of the broken object as separate entities (Shipley & Shepperson, 1990). Older children and adults do not make this counting error. This raises the question of why children seem predisposed to count discrete physical objects (DPO), and why this type of error is robust in the pre-school years but appears to disappear spontaneously by age 6.

(Insert Figure 1 about here)

In the Shipley & Shepperson (1990) study children were presented with a line drawing of a set of forks (see Figure 1). When asked, "How many forks are there?" children counted each part and whole object separately and arrived at the total of 6. Shipley & Shepperson concluded that preschool children have a strong tendency to treat each DPO as a countable entity and that this tendency diminishes with age. This counting bias does not appear to be related to children's perception of the two fragments as part of the same object. Some children in their study drew attention to the broken fork, asking why it was broken, or even commenting that the two parts were part of a single fork. Since children did not hold the belief that each of the two parts represented a different whole object, and should not have perceived each part as contributing to the total number of whole objects, the counting error is puzzling. Shipley & Shepperson (1990) even made this 'wholeness' explicit to the children in the second part of their experiment by telling them, "This and this (pointing at the two separated parts) together make a fork. So this and this…are one fork. Can you count the forks again?" (1990, pp.117). This resulted in some children changing their count strategies. Some subsequently omitted one whole object from the count, whereas others counted an object twice. After the experimenter's intervention the children recognised that a modification of their counting strategy was required, but they did not understand why. Shipley & Shepperson concluded that this provides additional evidence of the salience of DPOs for purposes of counting.

Dehaene (1997) claims that the DPO counting error arises from the fact that the human brain is endowed with innate beliefs about the properties of objects. Other psychologists have noted the primacy of discrete objects in the infant's conceptual system (e.g., Huntley-Fenner, Carey & Solimando, 2002; Leslie, Xu & Scholl, 1998). Deheane bases his argument on research (e.g., -Spelke, 1994) showing that infants have innate principles governing how they make sense of the physical world. One of these innate principles states that the same object cannot simultaneously occupy two separate locations, a maxim that serves the infant well in its sense-making activities. These principles form the foundation of numerical competence seen in infancy, and enable the young infant to discern how many objects are present. The maxim *'Number is a property of sets of discrete physical objects'* is therefore deeply embedded in the infant brain and persists to a much older age where it eventually, as with the DPO counting bias, has a negative impact on some aspects of mathematical development (Dehaene, 1997, pp.60-61).

Several alternative explanations for the DPO bias have been offered. For example, Sophian and her colleagues suggest that young children do not understand the significance of the counting unit (Sophian & Kailihiwa 1998). Sophian (2006) suggests children have an incomplete ~~understanding ,which~~understanding, which can be at odds with their beliefs or that they cannot apply what they learn (Sophian &

Madrid, 2003)~~,~~. Children may focus on separate entities simply because this is the most familiar way to count, and failure to understand the counting unit may reflect a lack of conceptual understanding of counting. Fuson (1988) found that if 3-year-old children were asked, “So how many are there?” after they had counted a set of objects, they would frequently count again. Procedural competence often precedes conceptual knowledge in many cognitive domains (Karmiloff-Smith, 1992; Messer, Pine & Butler, 2008~~) and~~) and this may be true for number too. Thus, by 3 years old, children may have efficient procedures for counting in place, but may not conceptually understand its quantitative significance. Without conceptual understanding, children may not see the need to adapt their counting strategy appropriately when presented with the broken object, and will persist in applying the one-to-one matching principle that underpins their counting procedure.

The DPO bias in young children has been shown to be quite difficult to eradicate. For example, despite using markedly different linguistic instructions in the object counting task, children persist in counting physical entities, even when the component elements are presented sequentially in an animated film (Wagner & Carey, 2003). Other research has shown that DPOs may not be the only physical variables in the array that preschool children can identify and count (e.g., Giralt & Bloom, 2000; Wagner & Carey, 2003, Experiment 2). This is not incompatible with DPO having a primacy, however. The presence of a marked developmental pattern, and the relative strength of the DPO bias over other experimental manipulations, does suggest it has some special developmental significance.

These findings and explanations are consistent with evidence from other cognitive domains where children adopt a rule-bound way of thinking or over - generalise a rule. Karmiloff-Smith (1992) claims that, in order to redescribe implicit, procedural knowledge about the world into explicitly available conceptual knowledge, a level of representation (called Level E1) must be formed in the interim that embodies some general principle or rule governing the domain. The advantage of this is that a lot of implicit knowledge is encapsulated in a single abstraction. The downside is that it can give rise to error prone behaviour. In the case of learning about language this leads to children adding '–ed' to past tense verbs and producing errors such as 'taked' on irregular verbs (Marcus, 2000). In a problem-solving domain, children over apply a rule that 'all things must balance in the middle' on a balance beam task and make errors balancing asymmetrically weighted objects (Karmiloff-Smith & Inhelder, 1974; Pine & Messer, 1999; 2003). Therefore, whether the child's maxim that counting involves enumerating discrete physical objects is an innately specified principle (Dehaene), or a rule-bound level of cognitive representation (Karmiloff-Smith), these theories both go some way to explaining its ubiquity and robustness.

Taken as a whole it seems that there can be a number of cognitive constraints on the child's ability to count two parts as the same object. The counting bias does not appear to arise from a perceptual error – children's responses in the Shipley & Shepperson experiment indicated clearly that they perceived the two parts as a single fork. Furthermore, Giralt & Bloom (2000) clearly show children can identify, count and track other object parts and elements. We suggest that lack of conceptual knowledge about the quantitative significance of counting, and also lack of a flexible counting strategy, are therefore more plausible explanations. However, to date neither has been rigorously tested empirically. These explanations would give rise to predictions that increasing conceptual knowledge and encouraging more flexible strategy use might help children to override the bias. On the other hand Dehaene's claim that the error arises from fundamental principles deeply embedded in the human brain, and Karmiloff-Smith's characterisation of Level E1 representations as an overgeneralised rule, predict that the tendency will be robust and resistant to teaching or intervention. The studies presented here are aimed at testing these predictions.

Apart from constraints imposed by the child's own cognitive system, or brain organisation giving rise to this counting bias, one must also consider the degree to which task variables play a part in biasing the children's responses. Shipley & Shepperson (1990) themselves went some way towards testing this by varying the question from "How many *things* are there?" to "How many *forks* are there?" The former question was more likely to affect the way that adults, but not children, responded. Wagner & Carey (2000) investigated a series of more subtle linguistic manipulations. In the broader developmental literature, there are countless studies that demonstrate how manipulating the form of the questioning or the meaning of the task in experiments with children affects how they respond. In studies of number conservation, for example, Rose & Blank (1974) demonstrated how repeating the question, "Which has more?" prompted children to change their answer the second time. McGarrigle & Donaldson (1978) showed that when an array of objects was altered not by an experimenter but by a 'naughty teddy', children were more likely to conserve number. Rather than just assume that the counting task described here reflects children's DPO bias, and explore why this occurs, this paper also questions the extent to which children's responses are driven by broader task demands. Some of these are addressed in the two studies described below in an attempt to answer the question 'How robust is the pre-school child's tendency to count discrete physical objects?' In both studies the instructions to the children specify the counting unit by the name of the object (e.g., fork), rather than a more abstract or less defined descriptor (e.g., thing) in order to minimise the likelihood of the DPO bias. Thus any persisting bias is likely to be quite strong.

Experiment 1

This experiment principally addresses the role that task demands, and the child's interpretation of the task, play in the manifestation of the DPO counting bias. To make the task more ecologically valid and relevant to the child's experience our first experiment includes a replication of the counting task, substituting for forks objects that children will have seen, and even have had experience of, as two separate parts. This includes an ice cream with its cornet and a lolly with its stick. Children's ability to count these separable objects, both intact and separated, is then compared with their ability to count objects that they are unlikely to have seen separated into two parts, a toothbrush, a sock and a pencil.

The second manipulation in the experiment involves making the task more meaningful for the child. Since it has been shown that children's number conservation ability is susceptible to task misinterpretation it is important to test whether their DPO bias could be similarly affected. Light, Buckingham & Robbins (1979) found that when a beaker was accidentally chipped and replaced with another, children's performance on a conservation task improved dramatically. In this experiment, as well as being asked to count arrays of intact and broken objects, the children encounter 'Naughty Ted' who accidentally breaks one of the objects in the previously intact array. This helps to reduce confusion for the child as to why the experimenter should be asking them to count a broken object. The counting task is presented as one that has to continue even though Naughty Ted has broken one of the items.

If the tendency to count DPOs is robust in pre-school children, it is unlikely that manipulating the separability of the objects or the context will affect it. However if, as others have suggested, the child's experience and interpretation of the task play a role then, by manipulating these factors, children may be helped to override their counting bias.

Method

Participants

Thirty-two children participated in the experiment, 19 were aged 3 and 13 aged 4. The overall mean age of the participants was 3 years 10 months. There were 21 girls and 11 boys, all attended pre-schools in Hertfordshire, U.K.

Materials and procedure

A within subjects design was employed, all participants taking part in three conditions: Control - counting 2 sets each comprising 5 intact items; Experimenter - counting 2 sets each comprising 4 intact and 1 broken item presented by the experimenter; Naughty Ted (NT) - counting 2 sets each comprising 4 intact items and 1 item broken by NT.

Within each condition the 2 sets of items comprised 1 separable set (ice cream, ice lolly, lollipop) and 1 unseparable set (toothbrush, sock, pencil). Age was a between subjects variable, with 4 levels: Younger 3 (between 3 and 3 years, 5 months); Older 3 (between 3 years, 6 months and 3 years 11 months); Younger 4 ((between 4 and 4 years, 5 months); Older 4 (between 4 years, 6 months and 4 years 11 months). Order was a between subjects variable. Half the participants took part in the Control, Experimenter then the Naughty Ted condition. The other half did the Control, ~~NaughtyTed~~Naughty Ted then the Experimenter condition.

The stimuli were created from coloured pictures of everyday items, each 12cm high x 5cm wide (approximately). The pictures were reproduced and stuck onto thick card and then cut around the outline so that they could be manipulated individually.

The separable items were an ice cream, an ~~ice lolly~~ice-lolly and a lollipop. The non-separable items were a toothbrush, a sock and a pencil. For the broken object, separable objects were parted where one would expect (e.g., the ice cream from the cone), unseparable objects were cut in half horizontally along the mid point.

The children were tested in a quiet area of the nursery. Two experimenters were introduced to the children and each child was asked if they would like to play some counting games. After introductions the experimenter told the child that some things would be put onto the table and the experimenter would like the child to count them and say how many there were.

Control condition: The first set of stimulus objects was presented in a line on the table in front of the child. The first experimenter then asked the child, "How many x (objects) are there?" After the child had responded the next array was placed on the table and the experimenter said, " Well done. Now can you tell me how many y there are?"

Experimenter Condition: This condition followed the same procedure as above but the arrays included intact objects and a broken one. If a child asked, "Why is that one broken?" the experimenter replied, "It just came that way", the procedure followed in the Shipley & Shepperson (1990) study.

Naughty Ted Condition: In this condition the experimenter introduced a Teddy bear puppet produced by the second experimenter. "This is Ted," the first experimenter told the child, "He's trying to learn to count. Would you like to show Ted how you count these (ice creams)?" An intact array of objects was placed on the table in front of the child. Before the child started to count 'Ted' began touching the objects and was heard to say "One…Two…oops". One object was knocked to the floor and, out of the child's view, replaced by Experimenter 2 with a broken one. The first experimenter then said to the child, “That was naughty of Ted wasn’t it? Now would you like to count these ice creams whilst Ted watches?” Hence the child saw the array first with intact objects, then an intact object apparently broken accidentally and replaced in the array as two parts.

There were 3 trials of each manipulation.

Results

The effect of task interpretation and meaning: Two different dependent variables were employed. The first was the tendency of the children to count all the separable items (i.e., to show the DPO bias). These results are shown in Table 1 for each of the experimental manipulations. The criterion for showing the DPO bias was counting 6 (and only 6) items in the Experimenter condition. The results show that 50% of the children showed the DPO bias in the Experimenter condition, and 47% in the Naughty Ted condition (i.e., 1 less child). Thus although all the children could ~~count -~~count - ~~as~~- as shown by the 0% in the Control condition - the contextualisation provided by the Naughty Ted manipulation was not effective in reducing the bias. The DPO bias is exactly the same for familiar as for unfamiliar objects, and it is clear that younger children do not show a greater DPO bias (X^2 (3, N = 32) = 1.543, *ns*).

Using this dependent variable, however, does have various limitations, although it is commonly reported. For example, data is lost about the actual count scores and the ~~power of the comparisons within-subjects are~~power of the comparisons within-subjects is limited for statistical reasons.

Table 1 about here

A second dependent variable was therefore used - the score of the number of items children actually counted. We checked the data, for under- or over-counting and it turned out that all the count scores of children ~~were either~~were 4, 5 or 6. Table 2 shows the descriptive data, split according to whether children showed the DPO bias or not. These results show a very robust and consistent pattern, with very little variation due to experimental condition or variable manipulation.

Table 2 about here

The effect of the different conditions was assessed by a change in the mean number of objects counted by the children in the Control, Experimenter and Naughty Ted conditions. The mean number counted for the two sets of 5 objects by children in the Control condition, was 9.9 (*SD*= .29). Therefore children were highly accurate at counting 2 sets of 5 objects. The mean number counted for the two sets of objects (4 intact, 1 broken) in the Experimenter condition was 10.81 (*SD* = 1.35) and in the Naughty Ted condition 10.75 (*SD*= 1.43). The count numbers were entered into a 3 (Condition, repeated measures) x 4 (age) x 2 (order) mixed Analysis of Variance (ANOVA). There was a main effect of Condition, F (2, 30) = 6.175, $p < .01$. There were no reliable effects of age or order and no reliable interactions. Therefore, the conditions alone affected the number of items counted by the children. Paired t-tests were conducted to determine which conditions differed. The Control condition differed reliably from the Experimenter condition, t (31) = - 4.37, $p < .01$ and from the Naughty Ted condition, t (31) = - 3.75, p = < .01. The Experimenter and Naughty Ted Conditions did not differ reliably from each other, t (31) = - .12, $p < .49$ *ns.*

Therefore, compared to the Control condition, children counted reliably more objects when both the Experimenter and Naughty Ted presented the array of intact and broken objects. The hypothesis that making the task more meaningful (by creating a context in which the object gets broken) is, therefore, not supported by these data. The DPO bias remained robust in the face of both the familiarity and context manipulations.

Experiment 2

Having failed to find any effect of task variables (familiarity of objects, interpretation of meaning) on children's counting bias, we next address other factors postulated as playing a role in supporting the bias. These include whether pre-school children have procedural but not conceptual knowledge of counting, the use of real rather than pictorially represented objects and whether children can be taught to adapt their one-to-one counting strategy to count the two parts as one.

It is important to determine whether children manifesting the DPO bias have conceptual /implicit conceptual/explicit -as well as procedural /implicitprocedural/explicit knowledge of counting. The theories of Fuson (1988) predict that children who know how to count but not why they count may be more prone to the DPO bias, since they simply execute a counting procedure without taking account of the quantification goal. That is, children who do not understand that counting is more than just something that we do *to* objects, that it has a quantifiable purpose, may be more prone to the DPO bias. Questioning the children about cardinality can test this. Hence, after the children in this experiment completed a baseline counting task they were asked, "So how many are there?" Children who repeated the last number were said to understand the cardinality principle. Those who counted again may lack this conceptual knowledge and be more likely to manifest the counting bias.

An additional manipulation in this experiment is to further increase the ecological validity of the task by substituting real objects for pictorially represented objects. Since counting is more often applied to real ‘things’ in the environment, and evolved as a mechanism for enumerating objects, it makes sense to test children with real objects rather than with pictures. As the previous study had shown that the type of object (familiar as separable or not) did not affect the children’s counting bias, this study used forks again but real ones, made of plastic, rather than drawings.

Finally, this study introduces an intervention designed to help children adopt a more flexible counting strategy that takes account of two parts of the same object. A pre-test/intervention/post-test paradigm is adopted, as this is an effective way of measuring the effects of intervention. The intervention includes both modelling of the new strategy and explanation (Siegler, 1995) since both these factors have been found to help children give up an ineffective strategy and adopt a more appropriate one (Pine & Messer, 2000). A delayed post-test is also employed, 2 –3 days following the first post-test, to see if any learning gains made have persisted

Method

Participants

Seventy-one children participated in this experiment, ~~26 were~~26 were age 3 and 45 age 4. The overall mean age was 4 years 3 months. There were 32 boys and 39 girls from pre-schools in Hertfordshire and North London. None participated in Experiment 1.

Materials and procedure

The experiment had a mixed design. Condition was the between subjects factor. Half of the participants experienced the Intervention between pre- and post-test and the other half, the Control condition, engaged in an unrelated activity for the equivalent amount of time. Allocation to condition was random. Age was also a between subjects factor. The within subjects factor was the children's pre- to post-test (1) and post-test (2) improvement.

The children were tested by two experimenters in a quiet area away from the classroom. Both experimenters were introduced to the children and each child was asked if they would like to play some counting games. One experimenter then carried out the tasks with the child whilst the other recorded the child's responses. Initially, to establish that the children could count, a set of plastic spoons was placed on the table before the child and she or he was asked to count the spoons. Afterwards the experimenter asked the child, "So how many spoons are there?" If the child repeated the last count number this was recorded as understanding of cardinality. If the child counted again this was recorded as lack of understanding.

Pre-test: The spoons were then removed from the table and a set of forks, 4 intact and 1 broken, were placed in front of the child. The broken fork was placed second from left in the array with the two parts aligned vertically with approximately 2 cm between the parts. The child was then asked to count the forks. After the pre-test the children were immediately randomly allocated to either the Control or Intervention condition. In the Control condition the forks were removed from the table and the child was given a paper and pencil maze to complete. In the Intervention condition the experimenter told the child that she was now going to count the forks. The child was asked to watch carefully how the experimenter counted the forks and to say how it was done. As the experimenter counted aloud she pointed, for each number, directly at each intact object but used a broader sweeping gesture over the two broken parts. The child was then asked, “Did you see what I did when I counted them? What did I do?” The child was allowed to answer freely.

Post-tests: Post-test (1) followed immediately afterwards and took the same form as the pre-test, requiring the child to count the forks again. The child was then praised and thanked and returned to class. For the delayed post-test (2) the experimenter revisited the school and all the children were re-tested counting the forks.

Results

Since the effects of the intervention were to be assessed via a change in count from pre-to post-tests it was important to select for the analyses those children who showed scope for improvement. Thus, those children who did not show the DPO bias at pre-test (i.e., counted 5) were excluded from the analysis.

Effects of counting real objects rather than drawings: This left 24 children who showed the DPO bias at pre-test and whose progress could be tracked through to the post-tests. Firstly, however, it was of interest to compare this proportion of the total number of children showing the DPO bias with that found in Experiment 1. In Experiment 1, 16 of the 32 children (50%) showed the bias. In Experiment 2, 24 of the 71 children (34%) showed it. No reliable difference between the number of children manifesting the DPO bias in the two experiments was found, using Chi Square analysis, X^2 (1, N = 103) = 2.44 *ns*. While it appeared that counting real objects (rather than drawings) reduced the manifestation of the bias across the two experiments from 50% to 34% the difference was not statistically significant (p = .09).

Effect of conditions on reduction in DPO bias: Next improvement in counting was assessed via the change in count by children in both conditions from pre-test to post-test (1) and post-test (2). Twenty-four children counted 6 at pre-test, 10 went on to experience the control condition, 14 the Intervention condition. Tracking individual children across trials revealed that of the 24 children who were counting 6 at pre-test, one third of these (8 children) had modified their count to 5 by post-test (1). All of these children had experienced the Intervention Condition; none of the children in the Control Condition modified their count. Chi Square analysis on these frequencies showed a reliable association between Improvement and Condition, X^2 (1, N = 24) = 8.57, $p < .01$. Nonetheless this means a high proportion of the children (66%) were still counting 6 and manifesting the DPO bias after the Intervention condition. Improvement was not affected by age since half of the children who improved were three years old and half were four years old. Examination of individual children's progress reveals that only 4 of the 8 children who improved from pre-test to post-test (1) maintained the improvement to post test (2). In other words half of them reverted back to the DPO bias after 2-3 days. However, 2 children from the Control condition, who showed the DPO bias at both pre-test and post-test (1) showed spontaneous improvement and were counting without the bias by post-test 2.

This pattern of results was confirmed by an analysis using the mean count scores. Considering only the children who showed the DPO bias, the mean count at first post-test for the Control group was group was unchanged at 6, while the Intervention group's mean changed to 5.42 (SD = .51), revealing that the intervention was effective. A 2 (trials, pre to post) x 2 (Condition, Control and Intervention) ANOVA confirmed a confirmed a significant main effect of Trial, F (1,1) = 12.22 $p < .01$. The interaction of Trial x Condition was also significant, F (1,1) = 12.22 p <

.01 confirming that children in the Intervention group had made reliably better progress by post-test (1) than children in the Control group. By post-test (2), 2 – 3 days later, the mean score at for the Intervention group was 5.64 (*SD* = .49) compared to 5.42 (*SD* = .51) at post-test (1), (see Table 1). A 2 (Trials, post-test 1 to post-test 2) x 2 (Condition, Control and Intervention) ANOVA found that there was no significant Main effect of Trial, F (1,1) = .319 *ns* and no significant interaction of Trial x Condition, F (1,1) = 2.41 *ns*. Children's mean scores had therefore not changed significantly by post-test (2).

Insert Table 3 about here

Understanding of cardinality: The final analysis looked at the differences in the progress of children who came to the experiment with understanding of cardinality compared to those who did not. Children were categorised into whether, when asked, "How many?" they counted again (no understanding) or repeated the last number (understanding). There was no association between understanding of cardinality and improvement as measured by a change of count from 6 to 5 from pre- to post-test (1), X^2 (1, N =24) = .40 *ns*.

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Discussion

In this paper we investigated the robustness of pre-school children's tendency to count discrete physical objects. We set out to determine whether this was affected by prior knowledge of the objects or misinterpretation of the task (Experiment 1) or by object reality, knowledge of cardinality, or strategy training (Experiment 2).

Overall these studies attest to the robust nature of the DPO counting bias. Experiment 1 found that that the DPO bias persisted regardless of the child's prior knowledge about the objects (i.e., whether or not they were separable) and when a meaningful context for the breaking of one of the objects was created.

A comparison of Experiments 1 and 2 showed that the use of real objects did not reliably reduce the manifestation of the bias; there was no difference in the proportion of children manifesting the bias in Experiment 1 compared with Experiment 2. In Experiment 2 children observed the experimenter using the correct counting strategy. The experimenter used one-to-one correspondence when pointing to and counting the intact objects, and made a sweeping gesture across the two broken parts whilst articulating the corresponding number. In order to engage the child's attention to the strategy the child was told beforehand, "Now I'm going to count them. Watch very carefully how I do it and then afterwards I'd like you to tell me what I did". Children's explanations varied from just "You counted" to "You counted all of them" to "You didn't count those two". This condition brought about improvement in one third of the children. However, half of these had reverted back to the counting error after 2-3 days, suggesting that the learning gain was temporary and that no lasting cognitive change had occurred. In all, only 6 children (25%) were not showing the bias by Post-test (2), 4 from the Intervention condition and 2 from the Control condition. This suggests that, as well as the intervention having minimal lasting effects, a small number of children improved spontaneously.

The results of Experiment 2 also suggested that the DPO bias was not related to children's understanding of cardinality, as measured by the single trial test used. The suggestion, from Fuson's theories, that children need to have conceptual understanding of counting as well as procedural competence in order to overcome the bias, finds weak support. Those children who responded with the last number word when asked, "How many?" were no more likely to overcome the counting bias than those who re-counted. However, Fuson points out that children may have learnt the procedure of repeating the last number in response to the question “How many?” without having real conceptual understanding of the quantification goal of counting. Therefore this experiment employs a somewhat crude measure of cardinality and further research into the relationship between understanding cardinality and the DPO bias would be advisable.

In a number of domains where children do not appear to have a particular competence, strategy training can bring about learning gains. Siegler (1978) found that 5 year-old children could be trained to encode more than one variable of a task and produce more accurate solutions. Flavell, Beach & Chinsky (1966) found that 5 year-old children’s recall of pictures of objects previously seen could be improved by training them to use a rehearsal strategy. Thus, young children frequently fail on tasks because they are using inappropriate strategies. Both Siegler and Flavell have shown that young children can be taught more appropriate strategies. However, both also found that the children did not apply the strategies spontaneously and often failed to apply them unless prompted to do so. A similar outcome has emerged from teaching these children to adapt their inappropriate counting strategy. One quarter of the sample appeared, after intervention, to have learned to override their DPO bias. Yet half of them did not maintain this improvement to succeed on the task 2 – 3 days later. However, it does need to be emphasised that the intervention was minimal and involved a short observation and the child explaining. Further research might explore the effects of more comprehensive teaching on the child’s knowledge, although more recent studies suggest that explicit instruction may not be as effective as repeated exposure and feedback (Blote et al., 2004)

These studies provide support for Karmiloff-Smith's notion of a Level E1 representation being formed during acquisition of a concept. The E1 representation is said to be a partial theory abstracted from procedures, (i.e., the first step towards conceptual knowledge). The Representational Redescription (RR) model states that Level E1 representations are robust, resistant to intervention, and result in rule driven behaviour that is often error prone. The DPO bias has been shown to have all these characteristics. Studies aimed at overcoming Level E1 behaviour on a balance beam task suggest the representation needs to be made verbally explicit before change can occur (Pine & Messer, 2000), although gesture can signal the child's readiness to change (Pine, Lufkin & Messer, 2004). Redescription, according to Karmiloff-Smith, can also occur spontaneously in response to internal pressure for change. The internal goal of the representational redescription process is to move away from E1 representations and towards the greater cognitive flexibility that comes with conceptual understanding. Children who manifest the DPO bias can be said to have Level E1 representations, since they lack flexibility and adhere rigidly to a one-to-one counting strategy.

The findings presented here suggest that the DPO bias remains inflexible through the pre-school years and, like some aspects of language learning and problem-solving, is, for a time, resistant to corrective input or contextual factors. For, despite its robustness, the DPO bias is short-lived. Though fairly common in a number of children at age 3 to 4, by age 6 it has spontaneously disappeared in all normally developing children. Future research may shed light on the precise mechanisms that bring about this change, which may turn out to be due less to external factors than to the self-organising properties of the cognitive system.

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Figure 1: Stimulus array found to elicit the DPO counting bias in pre-school children (from Shipley & Shepperson, 1990)

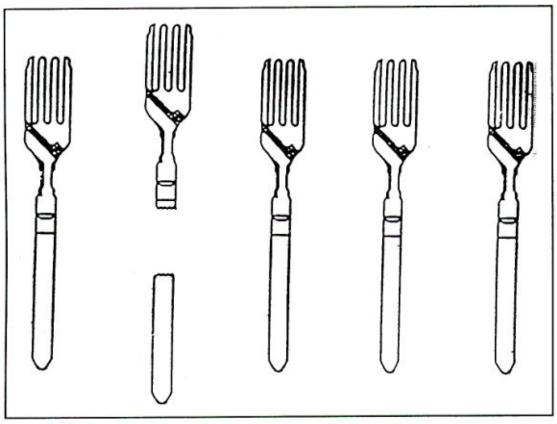

Table 1: The percentage (%) of children showing the DPO bias in each condition and stimulus manipulation.

Condition		**Percentage of children showing DPO bias**
	Control	0
	Experimenter	50
	Naughty Ted	47
Age		
	Younger 3	33
	Older 3	60
	Younger 4	57
	Older 4	50
Objects		
	Familiar	49
	Unfamiliar	49

Table 2: Mean count scores (and SDs) by Condition according to whether or not children show the DPO bias

DPO Bias		**Familiar objects**	**Unfamiliar objects**
	Control	5.0 (0)	5.0 (0)
	Experimenter	6 (0)	6.0 (0)
	Naughty Ted	5.94 (.25)	5.94 (.25)
No DPO bias			
	Control	4.81 (.40)	5 (0)
	Experimenter	4.81 (.40)	4.81 (.40)
	Naughty Ted	4.81 (.40)	4.81 (.40)

Table 3: Mean counts (and SDs) of those children showing the DPO bias in the Intervention and Control Groups at post-test (1) and delayed post-test (2) in Experiment 2.

Condition		**Post-test (1)**	**Post-test (2)**
Control	Mean	6.00 (0)	5.90 (.31)
	N	10	10
Experimental	Mean	5.42 (.51)	5.64 (.49)
	N	14	14