QUALITATIVE DIFFERENCES IN THE WAY DOWN SYNDROME AND NORMAL CHILDREN SOLVE A NOVEL COUNTING PROBLEM

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Introduction

We believe that the roots of human cognition are best understood through the comparison of the performance of different populations of subjects on similar tasks and through the comparison of a given population's performance on a variety of conceptually related tasks. Here we show that comparisons of Down Syndrome and normal children's solutions for a novel counting problem shed light on the nature of counting knowledge.

There are two different accounts of the development of counting knowledge. One of these is based on the assumption that the capacity to form associations underlies all concept learning, no matter what the domain of the concept. The second account is based on the view that conceptual development benefits from an initial, albeit skeletal, set of domain-relevant principles or constraints. In the case of counting, the assumption is that a skeletal set of counting principles serves both to focus children's attention on counting-relevant inputs, and to support the build up in memory of a coherent representation of counting-relevant knowledge.

Cornwall (1974) concluded that Down Syndrome (hereafter DS) children learn to count by using associative, rote learning procedures. This suggestion gains support from some of our own data (Gelman, 1982) as well as the emerging consensus that DS individuals can learn by rote, despite their difficulties when required to use conceptual
In their term the reational-constructivist group of Piaget, and Gellman (1967) gave the prototype of the association-performance model, as some details about the two class of models.

...
el, belongs to that class of models which grant learners some innate dispositions to focus selectively on those inputs that are relevant in a given domain. Whereas the association model presumes that it is sufficient to postulate the very general, all-purpose, mental ability to form associations, this class of models does not. The position is that it is necessary to grant that the young bring some implicit, yet organized, knowledge to the task of learning. The theoretical motivation for such an assumption derives from the fact that very young children do much to control the nature of their supporting environments. They are known to respond selectively to the stimuli presented to them. Further, there are times when the children actively seek out those inputs which foster their construction of knowledge within a domain (Brown, Bransford, Ferrara & Campione, 1983; Gelman & Brown, 1986). If young children are granted some skeletal representations, we have a beginning account of such self-initiated activities. The principles serve as enabling tools for learning. Skeletal sets of principles function to define the class of relevant inputs and therefore help the learner find those inputs that are relevant to learning in the domain in question. Similarly, they set the stage for the fleshing out, and development of, the skeletal principles themselves.

We prefer the second class of models, in part, because we see a need to account for how young children know what are relevant data for learning about counting and number concepts. Environments do not, by themselves, force themselves on the learners, who are actively involved in constructing their knowledge base. Instead learners select their environments; they determine what serves as relevant inputs. This concern for what we characterize as the problem of relevance is deeply related to Quine's (1960) discussion of "gavagai" and a review of it helps clarify the problem as it applies to number concepts.

Quine wondered how naïve language learners come to know the intended referent of the sound sequence "gavagai," even if the speaker points in the direction of the target item, say a rabbit. For, in the absence of any clues to the contrary, the speaker could mean ear, furry stuff, space beside the thing, etc. How does the naïve listener choose among these possible hypotheses, especially if the listener is a beginning language learner? Why should the child presume the speaker means rabbit? Similarly, why should the child presume that the sounds "one," "two," are not labels for objects as a whole? Put differently, what is there within the learner as characterized by association theorists that would bias the learner to treat some speech data as label-relevant and other speech data as counting-tag relevant?

Unless we take the position that children must already share some implicit hypotheses with knowledgeable speakers, for example that a novel "word" uttered in the context of an object probably refers to the object as a whole, our young charges are guaranteed to end up with some unshared interpretations of the environment. In other words they will be at risk with respect to their ability to learn the concepts that adults have and want them to master. To help dispel the reader's doubt that naïve learners would have such problems if we did not grant them some shared assumptions about the nature of counting, we turn to a consideration of the association account of how children might learn the English count list.

The learning-by-association account of counting is straightforward. The idea is that a knowledgeable speaker (e.g., a parent) points to each of a set of objects and then says "one, two, three," etc. The more the speaker in question does this, the more likely it is that the child will come to learn that the presented string of words can be used for counting. Let us assume that something like this has to be going on. Yet, it cannot be the complete story. For one, the point-and-label theory should also apply to the learning of color terms. Given the seemingly endless sets of colored preschool toys, picture books, and children's television programs that focus on color, it should be a trivial matter for young children to learn their color terms. But it is not: Surprisingly, the preschoolers have a very hard time learning color terms, this despite clear evidence that even infants perceive colors much as do adults (e.g., Bartlett, 1977; Bornstein, 1985).

Further, the point-label-associate account of how the children acquire the count words predicts that some of the children will think that the acoustic counterparts to
How the Counting Principles Help Support Learning to Count

It's a miracle about learning. The next section expands on why our first principles-first model of learning counting skills should involve which we mean to teach. It's clear that students have a great deal to learn about their early numerical patterns.

Many children have difficultly interpreting the kind of things that they count. When children are first learning to count, they are often overwhelmed with the number of objects they need to count. As they begin to develop the procedures that will be used to develop the counting principles, they need a great deal to learn about their early numerical patterns.
use the conventional count words to count. In fact, one does not even have to use words when counting. Witness computers. The only constraints on the nature of the tags are those given by the one-one and stable ordering principles, i.e. that it be possible to treat them as all different and as an ordered set. Should finger positions, marks on the sand, short term memory bins, etc., be adaptable to his function, then fine. This consideration is what motivated Gelman and Gallistel (1978) to distinguish between numerals and numerologs; they reserve the latter term for those tags which are count words in a given language.

Principles Help the Learner: Finding count lists in the environment - The above points regarding the absence of constraints on the type of items that can be counted, the source of the tags, and the order in which tagging can take place, bring us back to the question we raised in Section II. How do naive learners keep straight what string of words are or are not used for counting; how do children come to correctly sort their verbal environment into labels, words, color terms, etc., and do so without mixing them up at first? We submit they do this by taking advantage of the domain-specific principles they bring to the learning task. To expand this theme we contrast the counting principles with what is known about labelling principles.

Markman (1986) and Spelke (1988) each assume that children are biased to think that words used in the context of a novel object most likely refer to the object as a whole. Additionally, novices have a tendency to assume that once an object in a class has been assigned a label, that label applies to the other same-level members of the class (Au & Markman, 1987; Waxman, 1985). The idea is that like us, the young assume once a rose is a “rose”; a rose is a “rose” - despite differences in color, breed, size, number of petals, and so on, of the exemplars. Add to this our variant of Markman’s mutual exclusivity principle, this being that each same-level class of natural objects or artifacts shares but one name, and we end up with the following proposal: Very young children’s principles for labelling objects lead to their implicit hypotheses that: (1) Categories of objects share the same unique label; (2) once an item is labelled, it cannot be assigned another label if it is treated as a member of the same category; and (3) once assigned, that label must be assigned to other exemplars of the same-level category. If children make these implicit assumptions, they then have some clues as to what to expect over time as they continue to hear those words that serve labelling functions. For the words they have begun to assimilate to their lexicon should continue to follow the use rules that are dictated by the principles.

Now contrast the one-label-for-classes-of-like-objects constraints with the use rules that could operate given implicit knowledge of the counting principles: One way, although by no means the only way, to satisfy the stable order principle is to use a list of words to tag items. Therefore, on the assumption that this principle is available to structure the environment for children, ordered lists of words should be salient to them. But this principle cannot by itself tell the children how to use these lists. This depends on the availability of further principles. These principles indicate that, when counting, the same words can be used with different objects over trials, and, in contrast, that the same words cannot be used within a trial -- even if items are alike. Such constraints follow from the abstraction or item-indifferenc principle. In the absence of the stable-order and item-indifference principles then, the above list of the children’s assumptions about labels could well lead them to think the count words are in fact labels for objects.

Thus, it is a combined consideration of the stable order and item-irrelevance principles that leads to the conclusion that number words are not names for objects but instead are tags for counting. Add to this Shipley and Shepperson’s (1987) finding that young children will count any separably identifiable entities, including broken pieces of the same toy, and we see how they can know counting terms are not object classification terms -- at least not in the sense that labels or nouns are. The bottom line then, is that a child who is granted principles for organizing the verbal environment and its use over time, is given good reason to assume that labels and count words serve different linguistic roles and cognitive functions.
A part of contract - the idea that principles serve to

forgettable domestic and commercial contracts. The
forgetting of the principles of contract in order to
forget the law of contract. A contract is not a contract
unless it is a contract of contract. The result of a
contract is to create a contract of contract. If the
contract is not a contract, then it is not a contract.

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direct attention to the relevant inputs that can foster knowledge acquisition in a given domain is consistent with various constructivist theories of mind. Cognitive scientists' contentions that prior knowledge in a domain determines what and how other materials are interpreted and learned (Bransford, 1979; Mandler, 1984; Schank & Abelson, 1977) represent a similar class argument. So does the Piagetian view that stimuli can serve as food for a particular cognitive activity only when there is a requisite structure with which to assimilate that stimulus. The Piagetian proposal that preschoolers cannot help but fail seriation tasks, this because they lack the requisite seriation structures, is but one illustration of the general position that mental structures are what support the interpretation and use of environments. From this perspective, when preschoolers invent counting algorithms to solve simple addition problems we give them, it follows that they must be using a knowledge structure that is characterizable in terms of counting principles.

Focus on Novelty

The above considerations of the way a principle-first model could help a child solve novel tasks led us to focus on how DS and preschool children negotiated a novel counting task. We wanted to know whether both groups of children would deal with the same task in different ways and, if so, whether the differences could be attributed to differences in the way counting was understood by the children in the two different groups.

The Constrained Counting or the "Doesn't Matter" Task - In order to assess young children's understanding of the abstraction principles, Gelman and Gallistel (1978) asked the preschool children to solve what amounts to a novel counting task which we will call the Constrained Counting Task. In the Gelman and Gallistel study, children started out simply counting a row of 5 heterogeneous items. The constrained counting task began when the children were asked to count the same display in a special (or different, or trick) way, this being to count all of the items by tagging the second item from the left "the one". That trial complete, children were next asked to count again in the same special way, this time so that the designated target item was tagged "the two". Subsequent trials involved requests that the target item end up "the three", "the four" and "the five". There are a variety of solutions that one can use on this task. Some of the successful ones we have seen the children use are illustrated in Fig. 1.

Each row of Fig. 1 schematizes a heterogeneous set of 5 objects. The X inside a given circle indicates the posi-

Figure 1. The schemata of possible solutions to the Constrained Counting Task. Take X = n to mean "make this, the target item, the 1, 2, ... or n". The numbers over the schematized items indicate the count word used; the arrows indicate the flow of points made by a child as she pointed to items.
...
things suggest that children who possess the requisite competence but nevertheless fail their first attempt on a novel problem, can come to succeed if they are allowed to persist at the problem. Without explicit feedback, performance improves over trials. Surely, self-generated trials could not lead to success unless some implicit knowledge of the principles in the domains in question were available to help children constrain, and therefore develop their successive efforts.

The foregoing considerations led us to a design that allowed children to repeat a trial, either on their own, or in response to hints from us. Children who are given hints or opportunities to start again cannot improve unless they have some way to interpret the hints or monitor the output of a new effort (Wilkinson, 1984).

Our design varied the way we built in the plan to repeat instructions, and give hints, depending on whether the subjects were from preschool or DS samples. The experimenters worked with the preschool children were told that they could paraphrase instructions, or repeat crucial features of the instructions, or ask a child to do a trial again. The experimenters working with the DS children were allowed more options. In particular, they were allowed to introduce more explicit hints if the less specific ones failed to lead to improved performance. For this allowed us to see if the children that did not improve on their own could nevertheless recognize sample solutions and other explicit hints for what they were, that is relevant inputs to their problem at hand. They should if they have some implicit knowledge of the principles (See the Section - Principles Help the Learner: Finding counting relevant behaviors). But if the proposal that the DS children learn to count by rote is correct (Cornwall, 1974), such explicit hints should do little to improve performance (Campione, Brown, Ferrara, & Bryant, 1984).

Details of the Study

The Children: The Down Syndrome Children - The ten DS children who contributed the data presented here attended the Catholic day-school for retarded children. The Arch-

diose of Philadelphia runs the school for free and although most of the children at the school come from Catholic families, applicants of all faiths are considered and accepted. The school is in a modern, well-equipped building, with a large, attractive setting in a quiet neighborhood in an upper middle class suburb of Philadelphia. It has a dedicated and talented staff, a fact that is validated by its receipt of major awards for teaching excellence.

The population served by the school is predominantly white and represents a lower-middle to middle-middle socioeconomic class. All children attending the school live at home with their families. They are bused to and from the school on a daily basis. The DS children in our study were so classified by the school staff who used a combination of diagnostic tools and medical records when first interviewing possible admittees. Details from these records were not available to us; still we had no reason to doubt the information we were given as to which of the children at the school were DS children.

The DS children who contributed the results presented below were all but one of the 11 DS children in a class of 21. (Equipment failures account for the need to drop the other DS child). The children in the class as a whole ranged in CA from 9 to 13 years (Median = 11 years); and MA from 3-6 to 6-8 (Median = 5.6). Their I.Q.'s (as measured in 19 cases with the Stanford-Binet, and two cases with the WISC) varied from 43-73. The range and medians for the DS children in the study were 10-13 CA years (Median = 10.6); 4-0 to 6-10 MA (Median = 5.8).

Some, or all, of our sample of children participated, along with other children at the school, in one or more of a wide range of studies conducted by a group at the University of Pennsylvania. These included studies of language production and comprehension skills (much as the ones that Ann Fowler present in another chapter in this volume); causal reasoning; information processing styles; social cognition; and arithmetic skills. The data we present below come from the latter set of tasks. The focus is on the way children negotiated the Gelman & Gallistel constrained counting task and what the pretests revealed about their counting skills. On occasion we consider some additional data available to us, this because they inform
counting principles

69

Counting Principles

the preschool child - the preschool classroom - the preschool experience

the preschool experience

Cohen and Cohen

PP1(20).max
tails, see below).

In both the DS and Preschool studies, the children were given additional variations of the "doesn't matter" task, ones introduced to provide data on whether the children could be flexible in their choice of solutions. The DS children were given an 8-item version of the task after they completed the 5-item version. When the set size increases, there is a greater chance of forgetting which item is the targeted one. Therefore, one must either remember its position in the row or do something to make the item distinctive, e.g., move it up above the row a bit, rearrange the order of items in the row. Failure to do these and to instead persist at using developed solutions could index a lack of flexibility.

Preschool children were also tested with circular arrangements of a 5-item heterogeneous display. When items are in a row, what is the beginning and end are given by the arrangement itself. In the case of a circle, children have to monitor the items if they are to avoid violating the constraints of the one-one principle. They cannot simply do what they are used to doing, which is to keep counting until they reach the end of the row. There is no "end" unless one constructs one oneself. So again, children who use the same solutions for both kinds of displays could be characterized as inflexible.

Thus, in both studies we have data from a common condition as well as data from variations on this condition, variations that might shed light on the extent to which the children in each sample can be flexible and change plans given a change in the setting.

Assessments of Basic Counting Abilities - We were able to assess the children's counting levels in the two ways summarized in Table 1. The first relied on the regular counting trial that occurred just before the children had been introduced to the requirements of the constrained counting task. The pertinent summary statistics for this trial are shown in the top half of Table 1. The other measures of group levels of counting prowess are summarized in the bottom half of the table and were based on pretests designed for this purpose. Note that the children were tested more than once on a given set size so that we could determine whether they counted reliably.

Also note that the DS children were given a second counting test. Like the preschool children they were first tested without any demonstrations. Following that session they were tested in a Demonstration condition. Now the

Table 1
Down Syndrome And Preschool Samples Counting Skill

<table>
<thead>
<tr>
<th>Source of Data and Index of Counting Skill</th>
<th>Down Syndrome (No Demo)</th>
<th>Down Syndrome (Demo)</th>
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<tbody>
<tr>
<td>Data Source &amp; 4 YRS 5 YRS DOWN DOWN</td>
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<td>Counting Principle(s)</td>
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<td>Constrained Count Trial</td>
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<td>to Start Experimental Task</td>
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</table>

@ DS children had 3 count trials per set size and had to get 2 of 3 correct to be credited with the one-one and stable principles; at least one correct to be credited with the cardinal principle. Preschool children only had 1 counting trial per set size, unless they errored in which case a further trial was administered. If correct by the time the trial ended, they were scored as having the one-one and stable principles. See the text for a description of the separate cardinal task they received.
To the down from the descriptive property, some details re-

carried out the experiment. The primary point of the description is to make relations regarding the primary question. Then, the question is answered in the next paragraphs. The conclusion is made in the final paragraph.

size of the experiment, theoretical, and experimental.

The theoretical section covers the theories and models used in the experiment. It also discusses the limitations and assumptions of these theories. The experimental section describes the experimental setup and procedures. The results section presents the data collected during the experiment. The analysis section interprets the data and discusses the implications of the findings. The conclusion section summarizes the main points and suggests areas for future research.
every repeat of that trial, we ended up with transcripts that showed the children's sequence of points and count words. In addition, the separate columns to the right of these diagrams were used to enter transcripts of all comments and questions, as well as comments on the source of these (child or experimenter). These comments were entered so as to indicate when (before, during, after) the talk occurred relative to the counting behaviors diagrammed for the trial. If the experimenter demonstrated anything, this too was described in detail. Further columns on the transcription sheets, and again for each diagrammed entry, were used by two transcribers who together coded whether and when the children hesitated, counted slow or fast, paused, or made eye contact with the experimenter.

An independent observer was trained to read our transcripts and then used 17 of these to see if she agreed with a computer printout of summaries that were generated from these. These summaries included rates of success per trial, the number of times a child encountered a trial, whether children hesitated, restated a trial (with or without a probe), the amount of speech produced by the experimenter between repeats of a trial, etc. In all, excluding the diagrams and the details on these, the second observer checked our transcripts against 4060 separate sheets entries and agreed with them on all but twenty-nine occasions. Further, she only needed to return to three of the actual videotapes themselves to make sense of an entry on the transcript. This indicates that we succeeded at developing an interpretable transcription of the tapes and that summaries based on these were reliable. Hence, the coded data served as the source of input to the subsequent analyses.

What the Study Reveals About the Nature of Counting Knowledge

Overall differences in the Ability to Deal with Novelty: Our first pass at finding answers to our questions involved a consideration of overall levels of success on the constrained counting task. Fig. 2 plots the overall tendencies of children to generate successful solutions on their very first encounter with the question or by the time the trial had ended. (Recall our plan to allow the children to repeat a trial, either on their own or after receiving hints). Three salient results are shown here.

First, if we focus on the two DS groups of children (A and B), there is a clear difference favoring those DS children we identified as excellent counters (Group A). In fact, the two DS children performed at ceiling levels. Second, although both preschool groups outperform the remaining DS children, the two DS children in the A Group did best of all. Finally, the preschool children, especially the 4-year-old, improved much more than did the DS

Figure 2. The overall performance levels of success for each group of children tested on the Constrained Counting Task.

B group of children as they went from their first to final effort with the trial. This is our first clue that the bulk of the DS sample might not have benefitted from hints or self-corrected their initial efforts. A more de-
are especially salient. To understand what might have
some difficulty?, In this respect the x = 0, trial
result test to nonpresented
people this to have happened -- on trials as much as
not to report trials and did so just where one might ex-
-olds and young are the intuition presented down the oppo-
the button pressed in the: 8 show that cost the 2-year.

The button pressed in the: 8 return and clickers.

...
happened on the X = 3 trial, it helps to refer first to Fig. 4 which illustrates one possible set of solutions across all values of X, given that X is always in the second position.

From Fig. 4, one can see that the X = 3 trial places the greatest number of demands on the child. In the given example, it is the only trial which requires the child to skip an item more than once. A little reflection makes it clear that this is also the trial where a child would

Figure 4. Schematized solutions to a set of trials where the target item was always the same across trials with differing values of X.

Figure 5. Source of a child's repeat of a given trial: the child or the experimenter.
Figure 6. Mean number of experimental utterances by

Figure 7. Kinds and effectiveness of utterances given between

Figure 8. Children's first and final attempts to match a given

Figure 9. Mean number of experimental utterances by

In this article, mistakes are made so few mistakes to start, they are not represented

In this task, three groups of children participated. Since the two groups A & B children

In these children, the experimental differentials were observed. In position to self-initiate a second attempt, the

Differences in follow-up to an initial unsuccesful act

and the contrasted counting task as a given trial pro-

00 Gelman and Coleman
er group heard even half this much talk! Additionally, as can be seen in Fig. 7, none of the other groups received as much explicit help. Fig. 7 summarizes the kinds of hints children received and the extent to which a given kind of hint was used effectively. The rate at which the kinds of hints shown in Fig. 7 were offered is reflected in the total length of a given bar. For example, 5-year-olds encountered relatively few reminders that they were to assign a given tag to a given object.

It is important to realize that we scored a child as receiving a hint no matter how long the utterance. This means that Fig. 7 is a conservative way of illustrating the amount of help we gave the DS children. Yet, it is clear that it was the preschool children who were most likely to benefit from our hints. The effectiveness of a particular kind of hint is captured by the height of that bar. The extent to which the same kind of hint was or was not effective is captured by the length of portion of the bar that is above or below the horizontal axis.

Since most of the bars of the DS children are below the horizontal axis, we can conclude that they benefitted the least from the tendency of the experimenters to lend a helping hand. This overall effect supports the idea that these children were not working with a principled understanding of counting. Not only is it the case that these children did not self-initiate their follow-up efforts, even when given hints as to what to do, they failed to benefit from these hints, -- even when they were extremely explicit. The following protocol excerpts illustrate both kinds of explicit help they received and how little effect it had.

[Subject A, DS Group B] (x = 4 trial)

Experimenter: Make the scissors the 4. (Scissors are in the middle position.)
Child: (Starts by tagging the target item.) 4, 5. (He pauses at length after saying 5 and puts his hand on his head.)
Experimenter: What's wrong?
Child: I don't know.
Experimenter: Okay, let me show you another way to do it, okay? You can go like this. (The experimenter demonstrates.)
Child: (Counts along with experimenter who points to the objects.) 3, 4, 5.
Experimenter: You don't have to count them all in order. Okay, and another thing, if you want to move these scissors (points to target), you can do that. You can move them anywhere you want. Okay? So do you want to make it number 4 now?
Child: (He counts slowly across the array from left to right, hesitating slightly before saying 5.) 1, 2, 3, 4, 5.
Experimenter: Okay, now this time make them (the scissors) number 4. The last time you made them number 3. Make them number 4.
Child: (Counts from 1 to 5 skipping over the target but returns to tag the target as 5 rather than 4.) [Experimenter goes to x = 5 trial]

(x = 5 trial)

Experimenter: Make the scissors the 5. (Scissors are in the middle position.)
Child: (Starting with the leftmost item, the subject counts.) 1, 2, 5. (He pauses before saying 5, then holds his head in his hand.) Oh boy.
Experimenter: You want to start over?
Child: Yeah.
Experimenter: Let's see you make them number 5.
Child: (He proceeds to count again from the left) 1, 2, 3. (He pauses after 3 and again holds his head with his hand.)
Experimenter: Okay, you can skip it. Do you want to just skip it? Okay, number 5 (points to target) and when you get to 3 you just jump to the purse. Okay, let's start over.
Child: 1, 2, 3, 4, 5. (He proceeds correctly, following the explicit instructions of the experimenter.)

[Subject B, DS Group B] (x = 3 trial)

Experimenter: Make the candle the 3. (The candle is
child: (the new number appears) on this trial by stopping at the second position from the left (on the second trial, 1 to 7).
child: (the new number appears) on this trial by stopping at the second position from the left (on the second trial, 1 to 7).

(subject: 4, 6 years; 2 minutes)

(child: (the new number appears) on this trial by stopping at the second position from the left (on the second trial, 1 to 7).)

child: (the new number appears) on this trial by stopping at the second position from the left (on the second trial, 1 to 7).)
[Subject #7 (4 years, 5 months)]  
(x = 5 trial)  
Experimenter: Make the balloon the number 5. (The balloon is in the middle position.)  
Child: (He tags the second item from the left as 1 and pauses. He then repeats himself but continues by tagging the leftmost item as 2, and then the target item as 3.)  
Experimenter: (Interrupts the child.) I wanted the balloon to be number 5.  
Child: (He now performs perfectly on this trial by skipping the target item and returning to it to tag it as 5.)

[Subject #11 (4 years, 7 months)]  
(x = 3 trial)  
Experimenter: Make the (target item) the 3. (The target is in the second position from the left.)  
Child: Can this be number 2? (Points to the middle item.)  
Experimenter: Whatever you want.  
Child: (She starts by tagging the leftmost item as 1, skips over the target tagging the middle item as 2, and returns to the target to tag it as 3. She then pauses.)  
Experimenter: Did you get them all?  
Child: (She continues her count, tagging the remaining two items as 4 and 5. The trial is thus completed correctly.)

[Subject #27 (5 years, 6 months)]  
(x = 4 trial)  
Experimenter: Make the bone the 4. (The bone is in the rightmost position.)  
Child: I'm thinking about how to do this. (He hesitates for a long time then counts the items to himself.) I can do it if I move the bone to where the strawberry is. (Second position from the right.) (He then switches the two items creating a correspondence between the items in the array and the words in his count list. He counts, beginning with the leftmost item and counting across to the right tagging the items from 1 to 4.)  
Experimenter: Did you get everything?  
Child: (He points to the rightmost item which has not yet been tagged and says 5, thus correctly completing the trial.)

[Subject #28 (5 years, 7 months)]  
(x = 5 trial)  
Experimenter: Make the (target item) the 5. (The target is in the middle position.)  
Child: (She hesitates before starting, tags the rightmost item as 1 and stops.)  
Experimenter: We want this one (points to the target) to be number 5.  
Child: (She now performs perfectly on this trial by starting to count from the rightmost item, skipping over the target when she gets to it, and returning to the target to tag it as 5.)

[Subject #31 (5 years, 9 months)]  
(x = 3 trial)  
Experimenter: Now, make it (target item) the 3. (The target is in the leftmost position.)  
Child: (He starts with the second item from the left and tags as 1. He continues to the right with 2, 3, 4, and returns to the leftmost item to tag it as 5.)  
Experimenter: Can you count them and make this be number 3?  
Child: (He begins again with the second item from the left and tags it as 1. He next tags the middle item 2 and returns to tag the leftmost item 3. The trial continues with the child tagging the rightmost item as 4 and the item to its left as 5. The result is a perfect performance on this trial.)

The preceding protocols help illustrate another feature of the results plotted in Fig. 7. Normal preschool children received the kind of input our design called for, that is neutral statements or reminders regarding the constraints of the task. As regards the latter, these
Computing Principles

Concerted efforts of preschool children were less developed when a test of gross motor coordination was used. The results indicated that the children were less mature in their motor coordination. The findings suggest that further research is needed to determine the extent to which these findings are applicable to other age groups.

Pettit - reversi time, and not use the computational approach to provide an effective solution for the problem of the children's failure because they may fail to recognize the cause of the problem. Other researchers have also noted the importance of recognizing the causes of failure. These researchers have suggested that the children's failure may be due to a lack of understanding of the problem or a lack of understanding of the principles involved. Further research is needed to determine the extent to which these findings are applicable to other age groups.

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than were DS children to adhere strictly to the conventional count-list order. Although the preschoolers did make some effort to honor the conventional count list order on their error trials, they also were willing to alter the order, and thereby avoid violating the one-one principle. Of the 16 and 14 4- and 5-year-olds, respectively, who made any errors at all, 44% in each age group showed at least some inclination to alter the conventional counting order.

It is especially interesting that there is no age difference here. For the 5-year-olds surely had more reinforcement for using the conventional list than did the younger children. On a strict associationist account, they should have been more inclined to stick to the conventional count-list order. That they did not is consistent with our hypothesis that our preschoolers, unlike Group B DS subjects, were able to put principle ahead of habit -- at least some of the time. So is the fact that some of these young children laughed, or made it clear they were “fooling” or joking when they made errors that seemed to serve the purpose of meeting task constraints. (The extensive counting training offered to our DS subjects might account for the fact that even our two excellent counters maintained a consistent sound word order when they started to make errors, especially on their trials with 8 items.)

The preceding results add weight to our conclusion that the majority of DS children actually did learn to count by rote and that, despite the benefit of a curriculum that is designed to give them a great deal of counting experience, they did not induce the principles that govern counting. Indeed, if anything, this kind of rote learning seems to have produced less flexibility, a conjecture that is supported by the kinds of data Wishart (this volume) presented on the way DS infants deal with the object concept task. It also gains support from one further consideration of the preschoolers’ performances.

As discussed in the Section - Procedures, circular displays present a special problem to children should they think they are to recite a list of count words until they come to the end of a row. Unless they are able to take into account their initial starting position and then use this to signal when to stop reciting count words, they run the risk of continuing on and on and on. One clear sign that our preschoolers did not do this comes from the fact that they did better on their line trials than their circle trials! Whereas five children in each of the age groups turned in perfect performances on their circle trials, only 3 of the 5-year-olds did as well on their linear displays. This is hardly what one would expect if the children who are used to counting items in rows have learned to do so without considering the demands of the one-one principle. Indeed, given that children did somewhat better with the circular arrays, we can conclude that they were able to honor the one-one principle in a flexible way.

Summary of Differences - We have presented a variety of findings that all converge on the conclusion that normal preschool children are not only better able to deal with a novel counting task; they approach the task of generating novel solutions in ways that are qualitatively different than those used by all but two of our Down Syndrome children. They are much more inclined to self-correct their false starts, to understand subtle hints, and to vary their solution types as their target instructions and stimulus conditions vary on them. Further, when they do make errors, they are willing to alter the order of the tags in the standard count sequence, a fact which makes them less likely to violate fundamental counting principles, as compared to the majority of the DS children. The DS children seem not able to benefit from hints as to how to solve their novel problem, even when these hints include explicit instructions or demonstrations of possible solutions. Their patterns of responding are consistent with the hypothesis that their learning to count was controlled by a rote, associative learning process. Since the normal children’s patterns of responding are so different and fit well with the predictions made by a principle-first learning model, we conclude that qualitative differences in their favor are due to their being able to take advantage of a skeletal set of the counting principles, ones which enabled their novel generation of counting solutions for the Constrained Counting Task.
An interesting commentary: Process with caution.
conclusion that normal individuals benefit from the availability of counting principles from the outset, ones that support the acquisition of counting knowledge and the generation of novel solutions. Surely the reader is wondering whether it is possible to arrive at a principled understanding of counting without having started with some skeletal outline of it. We think not. Instead, we prefer to say that the path to such knowledge is over so much more treacherous when one cannot take advantage of such principled help. With such principles on hand, children can find their way through ambiguous environments for they have guidelines as to which inputs fit the equivalence class that is relevant to the learning. Even if we as teachers fail to present the data base in a way that would best nurture development, children have going for them an inclination to both use and extend their existing knowledge structures. These in turn provide ways of both collecting and storing a coherent set of relevant inputs. So even if these inputs are few and far between, disorganized, and dressed up with irrelevant details, the mental structures can serve to filter the good from the bad. Children who learn only as associationist theorists say they do, are at a disadvantage because they are especially dependent on others to structure their inputs. Put differently, it becomes especially important to develop teaching methods that package inputs in ways that might be expected to provide mathematical inductions. From our perspective, there is one clear educational implication of this consequence. We must arrange our teaching materials so that they are congruent with mathematical principles. Instead of drilling children in the count word sequence, we might better turn our efforts to teaching them that count words are only tags, that count words acquire their meaning when they are used in ways that are consistent with the counting principles, that it is not necessary to count from one end of a row to the other, and it does not matter what items are collected together for a count. It is a tall order for sure, but one we might try before deciding it cannot be met. To those who counter that the children should not be asked to deal with matters pertaining to the counting principles unless they have mastered the conventional count list, we respond: What about the 4-year-old children in our study who prob-ably were less practiced on the count list?

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Footnotes

1. David Premack organized a group of us to do comparative studies with chimpanzees, normal and/or retarded children. In addition to Gelman and Fowler, the group has included Lila Geltman and Deborah Keiser and students or visitors working with one or more of us.

2. We included sessions with 5 and 8 homogeneous items because we thought children would be forced to move the target item so as to mark its special status. Given they did even more poorly under these conditions, there will be no further mention of them.

REFERENCES


