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ABSTRACT

This study assessed estimation skills on both static and transformation (conservation) tasks on numerosities ranging from 3 to 16, and included addition and subtraction trials to control for response bias. A total of 148 four- and five-year-old children estimated the number of balls of yarn sewn on elastic straps, and participated in 1 addition, 1 subtraction, and 2 conservation trials at each numerosity of the transformation task. The children were classified into three groups based on their performance: (1) conservers, who gave at least one adequate explanation on a conservation trial; (2) transitionals, who did not explain adequately, yet quickly gave at least 90 percent correct judgements; and (3) nonconservers, who could not adequately explain the result and gave incorrect judgements. Contrary to the hypothesis, conservers were no more accurate than transitionals in number conservation tasks. (MDM)

COUNTING AND NUMBER CONSERVATION

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ABSTRACT

The relation of counting to number conservation was assessed. In addition to a number conservation task, the frequency and accuracy of counting were measured. Explanations based on number were also noted. Where there was an effect of group, the "transitional" group usually counted less but based more explanations on numerosity than conservers or nonconservers. (Transitional subjects had nearly perfect performance--and made their judgments quickly--yet did not give adequate explanations.) The implications for theories of conservation learning are discussed.

INTRODUCTION

Piaget and Szeminska (1941) argued that skills at estimation (counting or matching) were irrelevant to the development of number conservation. Klahr and Wallace (1973), on the other hand, indicated that accurate estimation skills are required for conservation learning. Their position has received support from Siegler (1981); Fuson, Secada, and Hall (1983); and others. Saxe (1979) agreed that estimation skills precede number conservation, but noted that these were often not accurate enough to be the foundation for number conservation learning.

Several issues still need to be addressed. Saxe assessed estimation skills, but did not check for their use during the actual conservation task. Fuson et al. observed estimation procedures used to solve number conservation problems, and reported that correct judgments were more likely after training on counting or matching. However, Fuson et al. did not control for response bias and only used one relatively small numerosity to assess number conservation. As Siegler (1981) has argued, children's understanding of what transformations do change number (addition and subtraction) need to be studied along with those that do not (e.g., a length transformation).

This study assesses estimation skills on both static and transformation (conservation) tasks on numerosities ranging from 3 to 16, and includes addition and subtraction trials to control for response bias. It also notes when, where, and how accurately estimation skills are used during both tasks.

METHOD

Subjects were 148 four- and five-year-olds. Stimuli were balls of yarn sewn on elastic strips. One row was stretched for a length transformation. Stimuli were added or subtracted via snaps on the elastic strips. There was one addition, one subtraction, and two conservation trials at each numerosity of the transformation task. There was one unequal and one equal numerosity comparison at each numerosity of the static task.

Due to extended probing for "adequate" explanations, conservation trials on the transformation task included up to six points where children could choose to count or match items, plus one point where they were explicitly asked "How many?" Explanations solicited on the transformation task provided information regarding inferences subjects made about number (whether or not estimation procedures were used).

RESULTS

Children were classified into three groups based on transformation task performance. Conservers gave at least one adequate explanation on a conservation trial; transitionals did not explain adequately, yet quickly (without estimation) gave at least 90% correct judgments; and nonconservers both couldn't explain and either gave incorrect judgments or estimated to arrive at a correct solution regarding the equivalence of the two arrays. There were 71 conservers, 24 transitionals, and 53 nonconservers. Conservers and transitionals gave a significantly greater number of correct judgments than nonconservers on both the transformation and the static tasks.

use of estimation: static task

There was no significant difference among groups in frequency of observed estimation, but conservers overtly estimated the most often (21% of trials) and transitionals the least often (10%). This result was unexpected; it is unclear how conservers and transitionals "solved" this task if not through accurate estimation procedures. Features of the particular stimuli used may have allowed for other perceptual or partial matching strategies to lead to correct judgments. Still, better performance of conservers and transitionals indicates that they responded to more appropriate number cues than did nonconservers.

method of estimation: static task

Observed methods of quantification included incomplete estimation procedures (usually counting only one row), counting or matching items multiple times, and complete (but not multiple) counting or matching. Groups were not found to differ in methods of estimation.

accuracy of estimation: static task

Accuracy of estimation was scored as follows: absolute numerosity correct for both rows; relative numerosity correct for both rows (but absolute numerosities incorrect); absolute and relative numerosity incorrect for both rows; or no absolute numerosity given. There were no significant differences among groups in accuracy of observed estimation.

use of estimation: transformation task

There was no significant difference among groups in the number of times they chose to estimate across all trials. When the various choice points were examined, however, there were clear group differences. Nonconservers more often estimated before giving a judgment on equivalence; transitionals did so when asked to explain their judgment; and conservers counted or matched to justify their judgment and explanation upon repeated questioning. Transitionals also estimated more often when asked "How many?" (See Table 1.)

Insert Table 1 about here

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method used: transformation task

Transitionals showed the greatest number of instances of incomplete estimation ($\overline{X} = 1.63$) and conservers the least ($\overline{X} = .92$), $p < .05$. There were no other differences among groups for complete counting, complete matching, or multiple estimation.

estimation accuracy: transformation task

Nonconservers gave more inaccurate statements of absolute and relative numerosity than did either conservers or transitionals ($p < .001$). There was also a tendency for conservers to report correct absolute numerosities for both rows more often (13%) than transitionals (11%) or nonconservers (9%), $p = .07$.

explanations related to number

Transitionals gave more absolute-numerosity-based explanations (32%) than either conservers or nonconservers (both 14%), $p < .001$. Transitionals also gave the highest number of relative-numerosity explanations (16% vs. 10% for nonconservers and 7% for conservers, $p < .01$), e.g., "I have the same number" or "I have 12 and you have 12." (The latter is <u>not</u> correct in terms of absolute numerosity.)

DISCUSSION

Although they did not estimate more often than other groups on the static task, nonconservers did attempt to count more often before giving a judgment of equivalence on the transformation task. This finding is consistent with the idea that estimation skills are being used to learn about number conservation. On the other hand, if estimation is required for number conservation, conservers should engage in more complete estimation procedures and be accurate more often in terms of both absolute and relative numerosity. These predicted results were not obtained. Conservers showed no advantage over nonconservers on the static task for accuracy and no advantage on either task for method of overt estimation. As Saxe (1979) has argued, inaccurate estimation procedures on the part of conservers seem contrary to the idea that counting is a prerequisite to conservation learning.

Although the performance of transitionals is as good as that of conservers in terms of correct judgments across numerosities, they count, if anything, less often than the other two groups (except for more incomplete estimation on the transformation task). They are, however, more focused on both absolute and relative numerosity in their explanations. This may be because they realize that number-based explanations are still "better" than most others (length-based, for instance), and also that estimation can be used to "prove" their judgments are correct. Again, their inaccuracy at estimation is problematic if we assume number conservation is learned through estimation procedures.

It might be most parsimonious to assume that children develop estimation procedures before number conservation simply because number names and counting are encouraged by parents and preschools. Other research indicates that children's reliance on counting and other estimation procedures is dependent on both the broader social context and specific components of the experimental situation (e.g., Tollefsrud-Anderson, Campbell, Starkey, & Cooper, 1992). Situational variants may account for the relatively low level of estimation observed in this study, especially on the static task, where estimation would be the most optimal strategy.

It is still possible that children discover number conservation through subitizing of very small numbers, and later accurate counting or matching of slightly larger numbers. These developments might then contribute to application of this principled understanding to even larger numerosity arrays.

TABLE 1

% of trials with overt estimation on transformation task

	C	T	N
total percent	15	14	17 (NS)
initial equivalence	16	6	16 (NS)
before judgment (Nonconservers count to solve.)	8	2*	14*
explaining judgment (Transitionals count to explain.)	9	21*	9
"How do you know?" (Conservers count after probing.)	15**	11	3**
asked "How many?" (Transitionals count more here.)	66*	89*	73

* = $p < .05$ ** = $p < .01$

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