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ABSTRACT

This paper questions evidence for the thesis that causal reasoning of older children is more logical than that of younger ones, and describes two experiments which attempted to determine (1) whether there are true developmental differences in causal reasoning, and (2) what explanations for developmental differences can be supported. In the first experiment a problem that was completely unfamiliar to the subjects was used, so that subjects could not base their responses on previous statements of parents or teachers. Results indicated a clear developmental difference. In order to generate plausible interpretations of this finding, an information processing model was constructed to describe the steps involved in performing the experimental task. Various developmental differences were tested using an interactional strategy. Siegler and Liebert's regularity-without-contiguity task was analyzed and different versions presented to children of different ages. Competing explanations of the developmental difference were tested. Findings indicated that the difference lay only in the subjects' ability to overcome the influence of the blinking lights of the computer used in the experiment. The use of such an interactional design is recommended as a procedure for directly comparing the strength of factors which are hypothesized as central by different theories. (GO)

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An information processing approach to children's causal reasoning[1]

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The work that I am going to talk about today is in the area of children's causal reasoning. However, the issues that I hope to raise go beyond the topic area and concern how we can best uncover and explore developmental differences in children's reasoning. First, I will describe how a developmental difference in causal reasoning was uncovered in an earlier experiment. Then I will talk about a recent study in which various explanations for the developmental difference were tested. Finally, I will point to some broader ramifications for the investigation of cognitive development.

Most tasks used in studying causal reasoning are taken directly from Piaget's work. Children are asked questions such as "What causes the tides?" or "What causes the wind?" Older children tend to respond with answers such as "the moon," "gravity," and "air currents." Younger ones, by contrast, indicate that their fathers or God are the sources of causation. On the basis of such evidence, Piaget and subsequent investigators have concluded that the causal reasoning of older children is more logical than that of younger ones. Yet are the changes on such problems in the area of logic, or are they changes in simple factual knowledge? Newton did not discover the law of gravity until the 17th century. The relationship of the moon to the tides was known earlier to sea-faring cultures, but what is the likelihood that contemporary 8- or 9-year-olds would discover them on their own? It seems most probable that such traditional questions do not evoke children's logic at all, but rather their remembrance of the sophisticated explanations of parents and science teachers.

To determine whether there were true developmental differences in causal reasoning, then, a totally unfamiliar problem was needed in which children could not rely on previous statements of parents or teachers; each child would evaluate the same data with no directly relevant prior knowledge. In the task used, children were asked to determine which of two possibilities was causing an electric light to go on: it could either be the activities of a perceptually salient "computer" with orange, green, and red blinking lights or the insertion of an IBM card into an unadorned gray "card programmer." The computer operated on a preprogrammed, moderately complex cycle; its activities were uncorrelated with the light bulb's onset. By analogy, it represented all the activities occuring in the world simultaneously but unrelated to the event to be explained. On the other hand, insertion of the card into the card programmer represented a specific possible cause with a specifiable relationship to the light bulb's onset.

In the initial experiment (Siegler & Liebert, 1974), we were interested in the classic causal variables of contiguity and regularity; we varied them in a simple factorial array. Thus, some of the five- and some of the eight-year-olds saw the light bulb go on every time immediately after the card was inserted into the programmer (contiguity and regularity); some saw it go on immediately after the card's insertion on one-half of trials and not at all on the other one-half (contiguity without regularity); some saw it go on every time but only after five seconds had passed since insertion (regularity without contiguity); and the remainder saw it flash on only one-half of trials and then only after five seconds had passed (neither contiguity nor regularity).

The results of this initial experiment indicated a clear developmental difference. Both five- and eight-year-olds chose the card programmer as the causal agent more often when the pairing had been temporally contiguous than when it had been delayed, but only the older children chose it more often when the light bulb went on every time than when it went on only one-half of the time.

At this point, the likelihood that there existed a true developmental difference in the effects of regularity on causal reasoning seemed quite great, but its explanation remained unclear. There were two major conceptual problems in approadhing the explanatory issue: how to generate plausible interpretations and how to determine which of the plausible interpretations were in fact effective. The first problem was solved by constructing an information processing model of the steps necessary to do the task--it was assumed that the source of the developmental difference would lie in ability to perform one or more of these processes. The second problem, testing the interpretations, was resolved by adopting an interactional strategy. Specifically, children of different ages were presented different versions of the basic task. The versions differed in their demands that particular component steps within the information processing model be performed. Presumably, if the developmental difference resided in unequal ability on a particular process, then removing the need to do that step would reduce the difference between age groups. Removing a step that was not an important source of the inequality would, by this logic, leave the difference intact.

In the current experiment, I applied this strategy to analyzing Siegler and Liebert's (1974) regularity without contiguity task--the task in which the light bulb went on each time the card was inserted into the card programmer but only after a five-second delay. The information processing model for the problem is quite complex and evidence necessary to fill in certain portions in detail is lacking, but the basic outlines can be conveyed in terms of a few broad steps. First, children need to accurately encode the instructions and to decide on criteria for when they will infer causation. Next, they need to note that despite occasional contiguous pairings, there is no consistent correlation between the activities of the computer lights and the light bulb's onset, and that there is a regular relationship between the bulb's onset and the card's insertion. Making this latter connection demands the ability to represent temporal intervals in memory, to compare them, and to note their equality or inequality. Finally, on the basis of this knowledge, children must infer that the relationship between the card's insertion and the light bulb's onset is causal, while the relationship between the bulb's onset and the blinks of the computer lights is not.

This model suggests a number of possible sources of the developmental difference. Younger children could fail to conclude that the card's insertion caused the light to go on because they misencoded the initial instructions; because they were unable to rule out a relationship between the computer lights and the light bulb's flashes; because shortcomings of memory prevented them from representing, comparing, or noting the equality of the five-second periods between the card's insertion and the light's onset; or because they noted all relevant relationships but did not infer that the card programmer was causal. Each of these explanations was tested in turn; however, before doing so, an effort was made to rule out two alternative explanations, extrinsic to the information processing model but possibly relevant to explaining the developmental difference.

One alternative hypothesis concerned the social psychological phenomenon of commitment. In the earlier experiment, children were asked to identify the causal agent each time the light bulb went on, including the first trial, before any regular relationship could have become apparent. The very act of making judgments may have produced in kindergarteners an artifactual commitment to continue choosing a specific causal agent, even if it meant ignoring the implications of changing knowledge. This possibility seemed especially plausible because over three-fourths of the kindergarteners in the earlier experiment had chosen the same object as causal on all six trials, compared to roughly one-fourth of third graders. Therefore, the procedure was changed so that no response was requested until the light had gone on six times. Under this condition, as previously, older children were substantially more likely to choose the card programmer as the cause when there was a regular five-second delay between the card's insertion and the light's onset than when there was no consistent relationship. Younger children were unaffected by the regularity relationship. The absolute numbers were quite dramatic; all 12 of the older children in the regularity condition chose the card programmer as the causal agent versus only 5 of 12 of the younger ones (Table 1).

The second alternative that I wished to rule out was the possibility that younger children processed the information in basically the same way as older ones, but were slower either in rejecting the inconsistent relationship or in detecting the consistent one. To test this hypothesis, the length of the trials period was doubled; rather than seeing the light bulb go on 6 times, children saw it go on 12 times, in each case 5 seconds after the card had been inserted into the programmer. This longer trials period had no effect; only 4 of the 12 kindergarteners chose the card programmer as the causal agent compared to 5 of 12 in Experiment 1 (Table 1). It thus appeared that the developmental difference might be accounted for by one or more of the operations specified in the information processing model.

First, the possibility was tested that the younger children in fact had gathered all of the information about the relationships of the computer's and card programmer's activities to the light bulb's onset, but that on the basis of this information they were reluctant to infer that the one relationship was causal. To eliminate the need to draw this inference, a second dependent measure was added. After the trials period, the light bulb was unscrewed; children were told that the experimenter would turn the computer and card programmer back on and that they should press the buzzer when they thought the light bulb would have gone on if it were still screwed in. The computer and card programmer were switched back on, and the timing of the buzzer press was recorded. After this, children were asked what they thought had caused the light to go on. If differential criteria for drawing the causal inference was the source of the developmental difference, younger children's buzzer presses presumably would be as accurate as those of older children, but the differences on the verbal measure would be expected to remain.

In fact, the nonverbal measure of knowledge revealed a very similar pattern to the verbal one. Of the 10 third graders, 9 pressed the buzzer within two and one-half seconds of when the light would have gone on--that is, at least two and one-half and no more than seven and one-half seconds after the card had been inserted into the programmer. Only 4 of the 10 kindergarteners met this criterion of accuracy. Especially interesting, the children whose buzzer presses were accurate almost always chose the card programmer as the causal agent, whereas few whose presses were inaccurate did (Table 2). Thus, the developmental difference was not due to differential standards for inferring a causal relationship.

The next step was to test whether the difference was due to misencoding of the instructions. Specifically, it was possible that when told to find out which object was causing the light bulb to go on, younger children precluded the possibility of a delayed but regular relationship, due to a more restricted definition of what constituted a cause. To eliminate this potential source of difficulty, the instructions were changed so that children were asked to find out what told them <u>when</u> the light would go on.

Again, the developmental difference remained--8 of the 10 older children had accurate buzzer presses versus 3 of 10 younger ones. Thus, misencoding of instructions was rejected as an explanation.

Finally, an attempt was made to determine whether the developmental difference was due to an absolute inability of the younger children to represent in memory, compare, and note the equality of the temporal delays between the card's insertion and the light bulb's going on., or whether the distracting qualities of the computer were responsible for the difference. To test these alternatives, the computer was removed. In all other respects, the procedure was identical to earlier phases; for obvious reasons, the buzzer press measure was the only one used. If the developmental difference was in absolute ability to represent temporal delays in memory, the difference would be expected to remain. On the other hand, if the distracting influence of the computer were responsible, the difference between third graders and kindergarteners would be expected to disappear.

Under these conditions, the developmental difference did disappear. Only one more older than younger child produced an accurate buzzer press--7 versus 6. Thus, the problem was not in memory for the temporal durations, but rather seemed to be in ability to overcome the distracting influence of the computer's lights or to reject their role as possible causal agents. Teasing out the precise nature of the difficult caused by the computer's activities is the next step.

This strategy seems applicable to a wide variety of problems in cognitive development. A number of consistent developmental differences have been uncovered--in conservation, seriation, class inclusion, probability learning, hypothesis testing, and other tasks. Many competing explanations have been proposed but rarely are these competing explanations tested against each other within the same procedure. This precludes direct comparisons of the strengths of factors hypothesized to be central by different theories. It also increases the number of procedural variables confounding theoretical interpretations while leaving unspecified their effects. Use of interactional designs, varying the age of the learner and the demands of the basic task, can alleviate these problems. In addition, proceeding in the present way allows strong rejection of the importance of certain theoretical explanations. Finally, the approach suggests a method for convergent validation of interpretations. If the processes underlying developmental differences on a task are understood, then either of two approaches should be sufficient to narrow the gap in performance: changing the task, by eliminating the hypothesized source of difficulty, or changing the child, by engendering mastery of the relevant operations through training.

References

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Footnote

[1]A more detailed description of the experiment described in this paper is provided in Siegler (1975).

Table 1

Kindergarteners' and third graders' causal inferences[a]

A. Experiment 1 -- 6 trials		
	Chose card program	Chose computer
Third grade		
Regularity	12	0
Non-regularity	6	6
Kindergarten		
Regularity	5	7
Non-regularity	2	10
B. Experiment 2 -- 12 trials		
Kindergarten		
Regularity	4	8

[a]Entries in table refer to absolute number of children choosing object as causal agent (N = 12/condition)

Table 2

Kindergarteners' and third graders'

buzzer presses and causal inferences[a]

(Experiment 3)

	Chose card programmer	Chose computer
Third Graders		
Accurate presses	8	1
Inaccurate presses	1	0
Kindergarteners		
Accurate presses	2	2
Inaccurate presses	1	5

[a]Entries in Table refer to absolute numbers of children choosing object as causal agent (N = 10/age group)