BRIEF RESEARCH REPORT

Training in Inductive Reasoning and Problem Solving

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The present study investigated the effects of an inductive reasoning training program for teaching children (Klauer, 1989b). The experiment assessed the effects of training and the range of transfer of the training achieved. The subjects were 34 third-grade primary school children of average ability. The children were matched on age, sex, and IQ. Children from the training condition (N = 17) received a 1-week course of training (five 30-min sessions). The results demonstrated a significant, positive training effect on children's performance of inductive reasoning tasks. A near-transfer was observed, i.e., children were able to solve tasks in which they had not been trained. These effects persisted for 4 months. Far-transfer, however, was not observed, because the children were not able to solve mathematics problems which relate to inductive reasoning, in which they had received no training. Implications for training children within the context of regular schools and the range of transfer are discussed. © 1995 Academic Press, Inc.

From time immemorial we have been trying to solve all sorts of problems. In the beginning, these problems were concrete ones, which, if adequately solved, increased our chances of survival. No wonder problem solving is seen to be a crucial human activity that understandably has a central place in the curriculum of schools. In the course of time, many research projects have been conducted aimed at investigating and developing problem-solving strategies in children. Since the early sixties, cognitive developmentalists have devoted a great deal of attention to experiments in which children are trained, for instance, to acquire concepts described in Piaget's theory. The majority of this research has focused on the empirical aspects of the Genevan perspective on learning, i.e., concepts of mid-childhood (Brainerd, 1978a, 1978b). Research into thinking processes in general and the effects of specially designed training programs that influence the children's cognitive development in particular, is theoretically and practically relevant. These research questions are continuing to receive a great deal of attention (Kingma, 1986; Klauer, 1992; Phye & Sanders, 1993; Resing, 1993; Tomic, Kingma, & TenVergert, 1993).

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Most problems, regardless of domain, require different reasoning strategies to be applied to arrive at a solution. One important problem-solving strategy is inductive reasoning. Induction is the process whereby one generalizes across a limited number of instances, examples, or observations in order to find a description that applies to them all. This process may result in a certain regularity or orderliness. By applying inductive reasoning, one is also able to make inferences, which, as it were, exceed the knowledge we possess at the moment (Holland, Holyoak, Nisbett, & Thagard, 1986). Induction enables us to make predictions about new possibilities—to anticipate results, as it were. Many aptitude tests of inductive reasoning ability typically include problem-solving items in which children are asked to complete a series consisting of pictures or numbers.

Without inductive reasoning, it is difficult to successfully perform such tasks as seriation, classification and spelling. When performing such tasks, frequent appeal must be made to the principle of analogy, which is an element of inductive reasoning. Consequently, inductive reasoning is of importance for the acquisition of new knowledge and skills (Goldman & Pellegrino, 1982). This way of reasoning (inductive) involves memory-based performance involving the application of prior knowledge acquired in a specific domain to problems encountered in a new domain (Sternberg, 1977).

A renewed interest in training inductive reasoning, i.e., beyond the context of aptitude testing, is demonstrated by Klauser (1989c), among others. To solve inductive reasoning problems, children are required to perform mental comparisons. Comparison processes provide the basis for the discovery of perceivable similarities and differences. Application of these similarities and differences allows the child not only to find regularities and order, but also to detect only seeming regularities, that may provide this basis for misconceptions.

TRAINING FOR TRANSFER

Researchers who are engaged in training inductive reasoning within the educational context are particularly interested in long-term effects. Training for transfer occurs when a more or less long-lasting change is observed in a child’s ability to solve a certain type of problem as induced by a training program. A positive transfer effect is considered an indication of such a change. While influencing cognitive development, it is especially important to investigate the range of transfer.

To evaluate the success of training, various transfer standards can be used. Researchers think differently about this matter. There is a standard for transfer of training commonly used in Europe which progresses from less to more stringent criteria (Tomic et al., 1993). For example, to have learned particular skills during training, a child must (a) give correct answers on tasks set during training (near–near transfer tasks, which concern identical or almost identical tasks used in training and in the (post) test); (b) give correct answers to questions testing a
concept that uses stimuli different from the stimuli used in training (near–far transfer tasks), (c) give logically acceptable explanations for the answers given on the tests in a and b, (d) pass a test on at least one other concept related theoretically to that particular skill (far–far transfer tasks), and (e) continue to perform steps a to d successfully several days or weeks after training.

Most researchers outside Geneva are using a range of either near–near or near–far transfer tasks as a standard to evaluate the effectiveness of training (Brainerd, 1978a), whereas the Genevan and Russian standard consists of near–near, near–far, and far–far transfer tasks (Piaget, 1957, 1964, 1975; Inhelder, Sinclair & Bovet, 1974; Galperin, 1957, 1966, 1967; Tomic et al., 1993). To evaluate the success of a training program in cognitive development, stringent transfer criteria should be used. Far–far transfer is considered to be especially strong evidence that a change in the child’s cognitive structure has occurred. However, for most educational purposes, observation of near–far transfer is sufficient (see Tomic et al., 1993). Measuring the range of transfer is thus important. For this reason we included some far–far transfer tasks in the posttests, i.e., mathematics problems that relate to inductive reasoning not included in training.

The present study was conducted in order to investigate the effects that Klaue’s training program has on children’s performance of inductive reasoning tasks. Second, in addition to any observed effects, it seemed important to also investigate the durability of the observed effects. Third, an important goal was to determine the range or types of transfer induced by the training program. The range of transfer of inductive reasoning training was near–far and far–far transfer.

Two training issues were also investigated. The first issue involved whether the training program could also be used by inexperienced trainers not working under the supervision of the program’s designer. This is an important question, because much of the research using the program has been conducted by the designer’s staff members. The second issue involved whether training was effective when administered in groups rather than on an individual basis. Two advantages of this approach are that it is an attempt to do justice to standard teaching practice and that children can provide each other with feedback about their solutions to inductive reasoning tasks (Kingma & TenVergert, 1993).

**METHOD**

*Participants*

Thirty-four third-grade primary school children from the same class participated in this investigation. The third-grade level was chosen in order to compare findings with similar populations in previous training studies (Klaue, 1989a, 1990, 1992; Phye & Sanders, 1993; Resing & Verbrueken, 1993). The training group ($N = 17$, 6 boys and 11 girls) had a mean age of 86.1 months, $SD = 3.4$, and a mean IQ of 109.1, $SD = 14.6$. The control group ($N = 17$, 6 boys and 11 girls) had a mean age of 85.9 months, $SD = 3.5$ and a mean IQ of 109.4, $SD = 13.1$. 
Design

During the pretest, 34 third-grade primary school children were administered the Culture Fair Intelligence Test, Form 1, abridged version (Cattell, 1950). The children were then matched on IQ, age, and sex. In each matched pair, one child was assigned at random to the training and one to the control condition. The 17 children from the training group received training—five 30-min sessions—on each school day during a period of 1 week. Within the same time frame, their control group counterparts—also 17 children—had to complete tasks from the regular school curriculum. One day after training, the first post-test was administered to the trained children and their counterparts in the control group. This test was repeated four months after the first post-test was administered.

Materials and Procedure

Training. A training program was used which was designed for the development of inductive reasoning and to foster program solving strategies in the domain of inductive reasoning (Klauser, 1989b). The rationale of the training program is that the aptitude of inductive reasoning consists of cognitive processes that refer to using analogies, generalization, discrimination, and a metacognitive monitoring strategy that involves the checking of objects and relationships for similarities and/or differences (see for sample items Fig. 1).

In the training program there are six forms of inductive reasoning tasks, namely generalization (similarity between attributes), discrimination (difference between attributes), cross-classification (similarity and difference between attributes), recognizing relations (similarity between relations), discriminating relations (difference between relations), and system formation (similarity and difference between relations). The program includes 120 tasks. In 15% of the tasks, abstract material is used. The remaining 85% consists either of concrete material, such as blocks that could be manipulated by the children or picture and figure problems from the children's everyday life. For more details about the training program, see Klauser & Phye, (1994).

Following the pretest, the children assigned to the training group received treatment each school day for a period of 1 week. Each of the five training sessions took about 30 min. The children assigned to the training group (N = 17) were trained in three groups of 6, 6 and 5 by three researchers, who were not involved in administering the pretests and post-tests. The trainers, who had no experience in teaching young children, were briefly instructed in the program's rationale and the training approach. Because trainers changed groups after each session, not every group of children got the same trainer during all sessions. At the beginning of the first training session, the child was given the opportunity to become familiar with the questions. When the child gave an incorrect response in a training trial, the researcher asked: "How do you know that?" or "Can you demonstrate that?" The child was then asked to perform the item again until he or she gave a correct response. Due to the importance of feedback in fostering transfer (Klingma & Ten Berg, 1993), the children got feedback from each other as well as from the trainer.

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Fig. 1. Sample items of the training program.
The training program is designed for at least 10 sessions. Since no more than 5 sessions could be planned, 24 rather than the usual 12 problem tasks were delivered for practice. This implied that children had to get through the program at an accelerated pace.

Transfer. Pre- and post-tests, administered prior to and following training, consisted of the Cattell (1950), Form I, abridged version. We only used scores on test items that are related to inductive reasoning. The test was scored according to the instructions given in the test manual. The test was administered to the training and the control group prior to training (pretest), after training (as a measure of near–far transfer), and 4 months following training (second or delayed post-test) as a measure of the durability of training for transfer.

Arithmetic tasks. During training, the children were encouraged both to describe relations between objects and to name the common attributes of objects. During training, various objects familiar to the children were used; numbers, however, were absent. An arithmetic test was constructed asking children to discover relations between numbers and to reveal common attributes of numbers. The arithmetic test consisted of four parts and 21 items.

In general, children of this age, about 7.2 years, possess the acquired arithmetical knowledge to solve such tasks. However, they are not sufficiently able to understand relations between the given numbers, nor are they able to name the common attributes of this numbers. The range of transfer between the training tasks and the mathematics tasks could be considered far–far transfer, because in the training program no numbers were included. Following the aptitude test, the arithmetic test was also administered as a post-test. The mathematics test was administered immediately after training and again four months following training. An introductory trial was given to familiarize the child with the arithmetic problems (see Fig. 2).

The pre- and post-tests were not administered on an individual basis, but as a group test by the researcher. This procedure was necessitated by time and budget constraints. It was unknown to the test administrator which children belonged to the training or the control group. Previous research shows (Klauer, 1989a, 1990, 1992; Tomic et al., 1993) that all materials, the inductive reasoning program, and the training procedure employed in the experiment are appropriate for average third-grade children.

RESULTS

Analyses were conducted to determine the main effects of training on immediate and delayed near–far transfer performance. To test the significance of differences between trained and untrained children, an analysis of variance was conducted. The $\alpha$ was established at the .05 level. Overall comparisons among groups indicated that the average total scores of the training group on the near–far

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**Fig. 2.** Sample items of the math test.
transfer tasks were significantly higher than those of the control group on the first (near–far) post-test, \( f(1, 33) = 4.6, p < .05 \). On the second post-test (4 month later) the near–far performance of the training group was still significantly better than that of the control group, \( f(1, 33) = 4.3, p < .05 \). No significant interaction effects were observed. Thus, it is clear that training in inductive reasoning successfully induced near–far transfer in Cattell skills, and that this transfer effect persisted at least four months after training (i.e., the second post-test). An effect that persists for 4 months is sufficient for educational purposes (Tomic et al., 1993). Means are shown in Table 1.

To assess the far–far transfer of the training program on children's inductive reasoning skills, children's scores on the mathematics test administered following training were analyzed. No significant main effects were observed.

**DISCUSSION**

Training in inductive reasoning was shown to be successful in teaching third grade primary school children to transfer (near–far) inductive reasoning procedures and strategies. Durability was also demonstrated. From an educational point of view, a training effect which is observable for 4 months and an induced near–far transfer are considered sufficient evidence of training effectiveness (Tomic et al., 1993). These results confirmed the earlier findings of Klauser (1992), Phye and Sanders (1993), and Resing and Verbraeken (1993) and strengthen their findings with the additional evidence of transfer durability. These results also demonstrate that inductive reasoning training can be applied in educational settings.

Besides the significant differences between the trained and non-trained children, the positive training effects have implications that are important educationally. In order to depart as little as possible from current educational practice, the children were not trained on an individual basis as in Tomic et al. (1993), but in groups. Unlike the designer of the training program, who has had very experienced staff members administer training in his own research, training in this

**TABLE 1**

<table>
<thead>
<tr>
<th>Post-test condition</th>
<th>Training group</th>
<th>Cattell b (near–far)</th>
<th>Arithmetic b (far–far)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate</td>
<td>Training</td>
<td>31.8</td>
<td>16.6</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>29.9</td>
<td>15.9</td>
</tr>
<tr>
<td>Delayed</td>
<td>Training</td>
<td>34.6</td>
<td>17.8</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>33.2</td>
<td>17.1</td>
</tr>
</tbody>
</table>

*Note.* bMaximum score was 48. bMaximum score was 21.
experiment was provided by trainers who had no experience in instructing young children. Furthermore, during a 1-week period with no more than five 30-min sessions, the children had to get through the program at an accelerated pace, which differs considerably from training in similar studies (Kingma, 1986; Klauer, 1992; Tomic et al., 1993). In spite of the differing conditions of this experiment, the results indicate that training provided according the description given above, can have a significant educational impact when conducted in the context of regular schools with average intelligence children.

Theoretically, results indicate that training in inductive reasoning did not induce a far–far transfer, i.e., the children were unable to generalize their newly acquired skills to a different program domain (mathematics). The question remains why the training program did not induce far–far transfer in this study.

Considering research cited above, we have no grounds for assuming that the nature of the training program is responsible for the fact that inductive reasoning skills were not transferred to conceptually different tasks. In our opinion, there are a few possible explanations for the failure to observe far–far transfer of training in this study. The first explanation is the accelerated completion of training. The program was designed to last at least ten 30-min sessions. Children assigned to the training group received a treatment of five practice sessions that took about 30 min each. In previous training research, training involved 10 or more sessions (Phye & Sanders, 1993; Klauer, 1992; Resing & Verbraeken, 1993; Tomic et al., 1993). It must be questioned whether the accelerated completion of training (massed practice) resulted in a loss of frequent and extended opportunities for reflection during practice (distributed practice). It is well known that there is a positive relation between opportunity to practice and inducing transfer (Kingma & TenVergert, 1993). Also, the fact that the trainers were inexperienced may be a factor in the induction of far–far transfer.

REFERENCES


