

MAIER'S (1931) TWO-STRING PROBLEM REVISITED:
EVIDENCE FOR SPONTANEOUS TRANSFER?¹

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Summary.—Transfer occurs when previous experiences facilitate problem solving, and often experimental subjects are explicitly informed of the connection between earlier source information and the target problem. Spontaneous transfer occurs when subjects are uninformed of the connection between events, yet benefit from the prior experience. Maier's two-string problem was used in four conditions: two conditions providing uninformed "hints" for target solution, one explicit hint condition, and a control condition. Two separate experiments indicated significant informed transfer when subjects were explicitly told to think of a pendulum, and a spontaneous transfer effect approached significance for subjects who saw the string swing during the instructions. The results are discussed in terms of the subtle yet consistent appearance of spontaneous transfer across many studies.

Transfer occurs when prior experiences influence later performance on a task. In an explicit transfer condition, subjects are informed of the connection between source information and a target problem, and transfer is evidenced by enhanced performance. Spontaneous transfer occurs when subjects are uninformed of the relationship between source information and the target problem, yet performance measures show enhancement. That is, when subjects are uninformed of the relationship between the two events, they spontaneously make use of prior experiences, often being unaware that transfer is occurring. It seems reasonable to believe that spontaneous transfer occurs quite often—given the number of problems humans solve daily, many problems are solved without a conscious, effortful review of past experiences. However, it is difficult to show significantly in the laboratory, and a number of attempts have not indicated spontaneous (uninformed) transfer but successfully showed informed transfer (Gick & Holyoak, 1980, 1983; Hayes & Simon, 1977; Perfetto, Bransford, & Franks, 1983; Reed, Ernst, & Banerji, 1974).

Although spontaneous transfer is difficult to demonstrate, it is not impossible. Under fairly constrained conditions, spontaneous transfer has been observed by using multiple presentations of source information (Gick &

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Holyoak, 1983; Lockhart, Lamon, & Gick, 1988), by carefully matching multiple features of source and target information (Holyoak & Koh, 1987), and by focusing subjects' efforts on the shared features of source and target information (Catrambone & Holyoak, 1989). Spontaneous transfer studies are often one of two types (Reed, Ackinclose, & Voss, 1990)—(1) presentation of a source problem followed by an analogous target problem (e.g., Gick & Holyoak, 1980, 1983; Hayes & Simon, 1977; Reed, *et al.*, 1974), or (2) presentation of some sort of critical information which can be applied to the target problem. This critical information can be the actual solution of a target problem embedded in a different context (e.g., Perfetto, *et al.*, 1983) or in the presentation of a word-association task which is intended to cue the target solution (e.g., Duncan, 1961; Weisberg, DiCamillo, & Phillips, 1978).

An early demonstration of spontaneous transfer of the second type was by Maier (1931) using the two-string problem. In this problem two strings are suspended from the ceiling out of the normal grasp of subjects, and the goal is to tie the two strings together. Typically there are a few small objects in the room which can be used, and the solution of interest (target solution) is for the subject to attach one of the objects to the string (using the object as a weight) and swing the string like a pendulum, allowing both strings to be reached at the same time. Other solutions can occur (nontarget solutions), however, and Maier noted three: tie the string to an object in the middle of the room, lengthen one string, and pulling in one string with another object. Maier (1931) found that out of his 61 subjects, 39.3% solved the problem using the target solution without any help from the experimenter. For subjects not solving the problem on their own, Maier gave them a *hint* (source information) by bumping into one string several times, setting it in motion. If that hint was unsuccessful, Maier handed the subject a pair of pliers and told him that the problem could be solved with the pliers alone. In this condition, 37.7% of the subjects in the study solved the problem using the target solution. It should be noted that subjects were given multiple attempts at solving the problem using the target solution; that is, if a nontarget solution was offered, subjects were then encouraged to solve the problem again using a different approach. Twenty-three percent (23%) of the subjects in the study were unable to solve the problem using the target solution even after receiving the hints.

Maier was particularly interested in the subjects in the hint group. In a postexperimental interview, subjects indicated that the solution came to them without conscious knowledge of the experimenter's bumping into the string. One explanation for these results is that spontaneous transfer occurred and that their problem-solving behavior was influenced by a prior experience; however, this influence was unknown (or unrecognized) by the subjects.

The present study is a conceptual replication and extension of the Maier (1931) study. The two-string problem has been used by others to study transfer, with Cofer and his associates (Cofer, 1951; Judson, Cofer, & Gelfand, 1956) finding that memorizing associations like rope, string, and pendulum facilitated target solutions, while Duncan (1961) found having subjects generate alternative uses for objects (such as pliers) did not facilitate two-string target solutions. In fact, the two-string problem has been used in a number of other studies as well (see Adamson & Taylor, 1954; Battersby, Teuber, & Bender, 1953; Birch & Rabinowitz, 1951; Gick & Holyoak, 1980).

EXPERIMENT 1

Relatively few uninformed transfer effects have been demonstrated. The vast majority of studies typically show significant informed transfer but uninformed transfer is nonsignificant (although usually above baseline). In fact, much of the early work was conducted by or inspired by Woodworth (1938). The 1931 Maier study stands out, however, by observing uninformed transfer in the two-string task. Although Maier did not report the results of any statistical analyses, that study is frequently cited in the literature. The first experiment was a conceptual replication of the early Maier study, utilizing the two-string problem.

Method

Design and subjects.—The type of instructions subjects were given varied among the four experimental conditions; a control group, an incidental nonverbal hint, an intentional nonverbal hint, and an explicit verbal hint. Frequency of target solution, that is, attaching a weight to one string and setting it swinging in motion, retrieving the other string, and waiting for the first string to swing back, was the measure of interest.

Sixty-four undergraduate students in an introductory psychology course in Southern Illinois University participated in the experiment for course credit. Sixteen subjects served in each of the four instruction groups.

Materials.—Subjects entered a room 1.63 m wide by 8.33 m long by 4.00 m high, with two 1.85 m long (1.59 mm in diameter) strings hanging 3.58 m apart, outside of the normal, unaided grasp of the subjects. Subjects were allowed to use any objects from the room except the experimenter's table and chair to solve the problem. The items available were pencil and click eraser, stack of paper with medium-sized binder clip, chalk, chalkboard eraser, large binder clip, and magic marker.

Procedure.—Subjects were tested individually. When each subject arrived, basic information was collected in an adjacent room, and each one was told about the general procedures of the study. A subject was then taken to the experiment room and each one was provided the basic instructions.

This is the two-string problem. What I want you to do is show me how you would tie these two strings together. You don't have to tie the knot physically, but show me how you would get them together. You can use anything in the room except what I'm using, like the table and chair. Don't rule out ideas in your head; just go ahead and try them out. You have 15 minutes.

Control condition subjects received only the basic instructions. In the incidental condition, the experimenter "accidentally" brushed against one of the strings while giving the instructions, setting it in motion. This was done as the experimenter and subject entered the room, and as the experimenter began giving the instructions. The experimenter always entered the room first, set the string in motion, and looked back to confirm that the subject saw the string swing. For subjects in the intentional group, once in the room the experimenter grabbed one string and purposely swung it in front of the subject while delivering the instructions, allowing the experimenter to verify that the subject saw the string swing. In the explicit condition, subjects were told at the end of the instructions, "As a hint, think of a pendulum." However, no actual movement of the string by the experimenter occurred. These labels, control, incidental, intentional, and explicit, are from the experimenter's point of view. Whether or not transfer occurred from either the uninformed or informed conditions is determined based on the results.

After problem solution (target or nontarget) or after 15 min. (if the subjects did not solve the problem), subjects were systematically questioned about how they arrived at the solution and what role, if any, the experimenter had in solving the problem. Those subjects who solved the problem (regardless of target/nontarget solution) were asked:

(1) How did you come up with the solution? (2) What made you think of that? (3) Was there anything in this study that gave you the idea? (4) Was there anything I did to help you to solve the problem? (5) How did that help? Subjects with no solution were asked (1) What kinds of things did you think of while trying to solve the problem? (2) Where did those ideas come from? What made you think of those ideas? (3) Was there anything in this study that gave you those ideas? (4) Did those ideas come from anything I did?

Results and Discussion

A 3×4 chi-squared analysis on the frequency of target, nontarget, or no solution occurrences in the four instructional conditions yielded a significant difference in the over-all frequency of solutions ($\chi_6^2 = 12.67, p < .05$); see Table 1. In general, frequency of target solutions increased from the control to the explicit group while the trend for the nontarget solution was in the opposite direction, decreasing across groups. The frequency of no solution was low and relatively constant across the four groups. To investigate the locus of the frequency differences, 3×2 chi-squared analyses were conducted comparing each instruction group with the others. No significant differences were found in the following comparisons: control vs incidental, control vs intentional, incidental vs intentional, and intentional vs explicit. Significant

differences were detected when comparing control vs explicit ($\chi_2^2 = 10.67$, $p < .01$) and incidental vs explicit ($\chi_2^2 = 7.39$, $p < .05$). Although neither of the uninformed groups (incidental and intentional) differed from the control group, it is of interest that the intentional group also did not differ from the explicit group. While there was significant transfer in the explicit group, this was not the case for the intentional group (compared to controls). Hence, the amount of transfer in the intentional group fell in between the transfer in the control/incidental groups and the significant transfer in the explicit group.

TABLE 1
PERCENTAGE SOLUTION FREQUENCIES: EXP. 1 (N = 64)

Response Type	Instructional Group			
	Control	Incidental	Intentional	Explicit
Target	44	50	62	88
Nontarget	50	31	19	00
No Solution	6	19	19	12

The incidental group was the closest approximation to the original Maier study, and there was no significant uninformed transfer compared to controls in this condition. Two reasons may account for the lack of significant uninformed transfer. First, there were design and procedural differences between the studies. The original Maier study was a within-subjects design. If a subject did not solve the problem after a period of time with no hints, then Maier gave the subject the accidental swing (incidental) hint. If the brushing up against the string hint did not work, Maier gave subjects a second hint (the pliers). Also, if Maier's subject solved the problem but the solution was a nontarget solution, the subject was asked to solve the problem again, using another principle. Given the within-subjects nature of the design, the appropriate comparisons and statistical tests are difficult to specify. Hence, Maier's results may not be different from the present results and the results of other studies which have not yielded statistically significant uninformed transfer (e.g., Gick & Holyoak, 1980, 1983; Perfetto, *et al.*, 1983).

The present study was a between-subjects design. Subjects were in one of the four instruction groups, and only had one attempt at solving the problem. Either the subject solved the problem with a target or nontarget solution, or had no solution. It may be that the multiple attempts at solving the problem in the Maier study made it more likely that subjects would eventually come up with the target solution, especially when hints were given—perhaps in some way similar to the multiple source presentations of Gick and Holyoak (1983). Further, hints may be more effective when they occur after the subject has spent some time trying to solve the problem, as in Maier's study.

In the postexperimental interview, subjects with a solution replied mostly that to solve the problem they (1) "just knew" that they had to swing one or both of the strings, (2) needed to lengthen one of the strings because the strings were too short, or (3) they did not know how they came up with the solution. Some subjects said the objects in the room gave them the idea since the instructions said they could use objects. Subjects in the explicit condition frequently reported that the pendulum hint gave them the idea of how to solve the problem. It should be noted that for the subjects in the incidental and intentional groups, no subject referred to the experimenter swinging the string.

Subjects who had no solution were asked similar questions which focused on what the subject was thinking about. Like subjects in the incidental and intentional groups who solved the problem, no subject who did not solve the problem reported the swinging string hint.

The Maier (1931) study is frequently cited as a demonstration of insight, and by design, uninformed transfer. The pattern of results in Maier's study, the present data, and previous work (e.g., Gick & Holyoak, 1980, 1983; Perfetto, *et al.*, 1983) are all very similar. Often one finds a significant informed transfer effect (as was the case in Exp. 1), but the uninformed transfer effect is smaller and usually nonsignificant. Exp. 2 was performed to increase the statistical power of the study and to reduce the number of nontarget solutions given by the subjects. This may increase the frequency of uninformed transfer by eliminating potentially interfering solutions.

EXPERIMENT 2

Exp. 2 is essentially a replication of Exp. 1 with some minor methodological changes and an increased sample. Methodological procedures should be assumed the same except when differences are indicated in the Method section below. The only substantive change, other than adding more subjects, was to reduce the number of objects in the room. This was done in an effort to reduce the frequency of nontarget solutions. The rationale was that, if there were fewer potential nontarget solutions, perhaps the effects of transfer would be more evident.

Method

Design and subjects.—The design of Exp. 2 was the same as that for Exp. 1, with four instructional groups. Solution frequency was the measure of interest. Ninety-six undergraduate students in an introductory psychology course at Southern Illinois University participated in the experiment for course credit.

Materials.—The same room as used in Exp. 1 was utilized but the only items available to subjects were a piece of chalk, a chalkboard eraser, and a magic marker.

Procedure.—The procedures followed in testing the subjects were the same as those in Exp. 1, with the only difference being that subjects were given 10 min. rather than 15 min. to complete the problem. The instruction conditions for the four groups, as well as the postexperimental interview questions, were the same as in Exp. 1.

Results and Discussion

A 3×4 chi-squared analysis on the frequency of target, nontarget, or no solution occurrences in the four instructional conditions yielded a significant difference in the over-all frequency of solutions ($\chi_6^2 = 24.14$, $p < .001$); see Table 2. To investigate the precise nature of the frequency differences, 3×2 pairwise comparison chi-squared analyses were conducted. No significant differences were found in the following comparisons: control vs incidental, control vs intentional, and incidental vs intentional. Significant differences were detected when comparing control vs explicit ($\chi_2^2 = 13.50$, $p < .01$), incidental vs explicit ($\chi_2^2 = 19.60$, $p < .001$), and intentional vs explicit ($\chi_2^2 = 10.34$, $p < .01$). One reason for conducting the replication was to increase statistical power and reduce potential interfering solutions, thereby showing a significant difference between the control group and either uninformed transfer group. That did not occur.

TABLE 2
PERCENTAGE SOLUTION FREQUENCIES: EXP. 2 (N = 96)

Response Type	Instructional Group			
	Control	Incidental	Intentional	Explicit
Target	42	29	50	92
Nontarget	29	38	12	4
No Solution	29	33	38	4

In comparing the change in results from Exp. 1 to Exp. 2, there was a decrease in frequency of target solutions and an increase in frequency of no solutions, with little change in nontarget solution frequency. The purpose of taking objects out of the room was to decrease nontarget responses and thereby decrease interference with the target solution. In essence this only increased subjects' ingenuity, evidenced by seeing an increase in body use (using foot to kick or grab string) or a new idea not even seen in Exp. 1, sticking the string onto the wall. Decreasing the time allotted may also have produced the increase in no solutions and a decrease in target solutions.

The verbal responses to the postexperimental interview questions were very similar to those in Exp. 1. In both the incidental and intentional conditions, no subject reported remembering the experimenter swinging the string, or that the hint served as an aid to solving the problem. For those subjects not solving the problem, their responses were very similar to those reported in Exp. 1.

GENERAL DISCUSSION

In considering the pattern of results from both experiments, why does the incidental condition, closest conceptually to Maier's original manipulation, not demonstrate uninformed transfer? Combined results ($N = 160$) are presented in Table 3. All the hints in the present study were given before any experiences in the room with the strings. It may be that the hint is more effective when given after a series of failures in finding the target solution rather than giving the hint prior to the subject expending any problem solving effort. Another difference between the studies was that in Maier's study, multiple nontarget solutions were allowed before subjects' testing was complete, and many more items were present in the room. In the present study, only one solution was allowed, and subjects were not given another chance to solve the problem. Further, in Exps. 1 and 2, 50% and 58% of the subjects, respectively, in the control condition solved the two-string problem using the target solution. This baseline performance may be so high that any type of effect may be difficult to demonstrate as significant, except for the 88% to 92% levels of the explicit conditions.

TABLE 3
COMBINED PERCENTAGE SOLUTION FREQUENCIES: EXPS. 1 AND 2 ($N = 160$)

Response Type	Instructional Group			
	Control	Incidental	Intentional	Explicit
Target	42.5	37.5	55.0	90.0
Nontarget	37.5	35.0	15.0	2.5
No Solution	20.0	27.5	30.0	7.5

Although the incidental condition in the present experiment was not significantly different from the control condition, the pattern of results is very similar to previous work. Informed transfer performance is very good and statistically significant while uninformed transfer performance (in the intentional group) is not statistically significant, but in absolute terms is superior to control group performance. This seems to typify the pattern of results in several uninformed transfer studies (Gick & Holyoak, 1980, 1983; Perfetto, *et al.*, 1983).

So what is the status of spontaneous transfer? In highly controlled situations, it can be shown significantly. However, in a number of between-groups studies (including the present one), spontaneous transfer effects are consistently present but small. Weisberg, *et al.* (1978) reported a 15% advantage for their uninformed hint group, Gick and Holyoak (1980) a 20% advantage for the uninformed group, and Perfetto, *et al.* (1983) a 10% advantage for the uninformed group. In the present study, the advantage of the intentional group (compared to controls) varied from 8% to 18%. In fact,

when the data are combined from both experiments (Table 3), the difference between the control condition and the intentional condition only approaches significance ($\chi_2^2 = 5.30, p = .07$). It appears that some subjects from the uninformed group benefit on the two-string task when given an intentional hint (swinging the string in front of the subject while delivering the instructions) without even remembering the hint. Spontaneous transfer is consistently present in a number of studies, but it is not a consistently robust effect.

Spontaneous transfer effects in problem-solving studies are subtle and elusive. Although it is difficult to demonstrate significant uninformed transfer in any one study, the effect consistently appears (and is consistently small). Researchers may have to adjust their approach to capture such subtle effects. For example, Novick (1990) found the transfer of problem representations between source and target events, not necessarily transfer of solutions. It may be that such global measures as target solution are inappropriate for capturing an elusive phenomenon such as spontaneous transfer.

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