

# Following the Wrong Footsteps: Fixation Effects of Pictorial Examples in a Design Problem-Solving Task

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Two experiments examined possible negative transfer in nonexperts from the use of pictorial examples in a laboratory design problem-solving situation. In Experiment 1, 89 participants were instructed to “think aloud” and were assigned to 1 of 3 conditions: (a) *control* (standard instructions), (b) *fixation* (inclusion of a problematic example, describing its problematic elements), or (c) *defixation* (inclusion of a problematic example, with instructions to avoid using problematic elements). Negative transfer due to examples was measured both quantitatively and qualitatively through verbal protocols. Verbal protocols ( $N = 176$ ) were analyzed for participants’ reasons for reference to the examples. In Experiment 2, fixation to examples was evaluated in nonverbalizing participants ( $N = 60$ ). Results of both experiments suggest that (a) although participants consulted the problem instructions, they tended to follow the examples even when they included inappropriate elements and (b) the fixation effects can be diminished with the use of defixating instructions.

*Keywords:* functional fixedness, design problem solving, pictorial examples, verbal protocols

Researchers in problem solving have studied the transfer of knowledge from one problem situation to another. On the one hand, transfer may facilitate problem solving (*positive transfer*) when a person uses knowledge or skills previously acquired (Gick & Holyoak, 1980, 1983; Holyoak, 1984). On the other hand, transfer may also hinder problem solving (*negative transfer*); participants may perceive analogies that do not exist because of the similarity of surface attributes among problems (Gentner, 1983). Thus, having solved an earlier problem makes it harder to solve a later one (Sternberg, 1996). Many problems, for instance, impose difficulties due to an entrenched *mental set* (i.e., a frame of mind involving an existing model for representing a problem) that the solver brings to the situation from experience (Kotovsky, Hayes, & Simon, 1985; Luchins & Luchins, 1959). *Fixation*, a notion introduced by the Gestalt psychologists (Duncker, 1935/1945; Scheerer, 1963; see also Weisberg & Alba, 1981), is an example of negative transfer in which one adheres to example elements or previous

solutions that may not be useful in the current problem-solving context.

Fixation effects have also been observed in the context of learning from pictorial examples. Smith, Ward, and Schumacher (1993) have shown that pictorial examples may constrain participants’ solutions in creative generation tasks. In a series of experiments, participants were asked to imagine and provide sketches of experimenter-defined categories (e.g., creatures to inhabit another planet). Participants who had seen experimenter-provided examples of category members prior to generating original ideas showed a significant tendency in their sketches to conform to those examples by reproducing example elements. These results are in accord with previous findings (Smith & Blankenship, 1991) as well as subsequent studies using different creative cognition tasks (see Ward, 1994).

The findings from the creative cognition experiments indicate that negative transfer may emerge in a broad range of domains in the presence of examples in pictorial format. In fact, recent studies in the field of engineering design have suggested that the presentation of examples with a to-be-solved problem may lead to fixation in design problem solving (Jansson & Smith, 1991; Purcell & Gero, 1996; Purcell, Williams, Gero, & Colbron, 1993). Problem solving in design is frequently susceptible to “mental traps,” namely, restrictions and mistakes introduced in the design process as a result of previous practice with design tasks, often impeding the generation of effective solutions (Lawson, 1997). On occasion, when faced with a novel design problem, designers tend to reproduce solution approaches they used in past designs and may not consider alternative, more effective design solutions. This tendency suggests that the presence of a pictorial example may impede the search for effective solutions.

Jansson and Smith (1991) were the first to document fixation in an engineering-design task. They hypothesized that design fixation might be caused by examples that sometimes accompany problems

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given to designers. Although intended to suggest other possible solutions, those examples might, instead, have an inhibiting effect, restricting the problem solver to the use of components of the example designs. Jansson and Smith performed four experiments to test their hypothesis. In their experiments, a design problem was given to engineering-design students. The task was to generate as many designs as possible to solve the problem. In each experiment, the fixation group received the problem with an accompanying example design, whereas the control group received the problem without the example. Participants' designs were scored for total number of solutions generated as well as for similarity to the example provided to the fixation group. The results of all experiments revealed that, although the mean number of designs was the same for both groups, participants in the fixation group included in their solutions significantly more elements from the example design than did participants in the control group. Moreover, the same effects were observed when the description presented with the example emphasized its negative characteristics. Most striking is that the same results were obtained even when students were explicitly instructed to avoid using the specific problematic features from the examples. Jansson and Smith (1991; see also Smith, 1995) concluded that the experimental groups showed significant design fixation, induced by the example. The replication of the effect in studies with professional engineers suggested that even years of professional experience were not enough to diminish potential fixation.

Purcell et al. (1993) extended Jansson and Smith's (1991) findings by examining the possible occurrence of fixation across different design disciplines and levels of experience. Participants were 3rd- and 4th-year mechanical engineers, 4th-year industrial designers, and 4th-year interior designers. In addition, Purcell et al. used a more comprehensive coding system than Jansson and Smith's to score students' solutions. According to their results, there was a clear fixation effect observed for the two groups of mechanical engineering students. In contrast, the fixation effects for the students in industrial and interior design were only marginally significant. Purcell et al. suggested that the complexity of the example design imposes attentional constraints on the design process, which could play a role in the occurrence of fixation. That is, a more complex pictorial example may draw on the cognitive resources of problem solvers, so that they rely more on the example elements to provide a solution.

### The Present Study: Overview and Design

The use of examples as learning aids across a range of problem-solving tasks may not always be beneficial for the solver. The advantage of examples appears to depend on the situation, and, in fact, using examples might even be detrimental to performance in a variety of circumstances. The detrimental effects of negative transfer, thus, become particularly important if one takes into account the overwhelming tendency of participants to prefer worked-out examples to task instructions, a tendency that remains unaffected by the informational adequacy or the specificity of the instructions (e.g., Chi, Feltovich, & Glaser, 1981; LeFevre & Dixon, 1986; Pirolli & Anderson, 1985). The surface properties of worked-out examples are hypothesized to overshadow deeper structural properties of to-be-solved problems, thus erroneously priming participants' solution attempts toward the solution de-

picted in the example. Furthermore, participants exhibit an "attitude" against instructions; namely, they seem to be particularly reluctant to use the instructions provided in problem-solving tasks and often completely ignore them or read them only partially. LeFevre and Dixon (1986) found that when instructions and examples provided conflicting information, the vast majority of participants (92%) preferred to follow the example, irrespective of its accuracy.

Despite the benefits of participants' use of examples on the effective acquisition of problem-solving skills (e.g., Catrambone, 1994, 1996; Chen, 1995; Ross & Kennedy, 1990) and the wide use of pictorial examples as problem-solving aids in a variety of educational settings (e.g., Doornekamp, 2001; Lim & Moore, 2002; Noh & Scharmann, 1997), there is a relative paucity of research on the specific circumstances under which the use of examples benefits or impairs the solver's performance. Most important, very few studies in psychology (e.g., Jansson & Smith, 1991; Smith et al., 1993) have examined the cognitive mechanisms underlying possible negative transfer effects following the use of examples. Sternberg and Ben-Zeev (2001) pointed out that very few studies have examined the effects of examples when they are inappropriate for the problem solution. In fact, these researchers refer to the potential beneficial effects of training students with negative examples. A similar view was supported by Ross and Kilbane (1997), who noted that the effectiveness of incorporating contrasting examples as an instructional technique has yet to be adequately evaluated.

The primary aim of the present research was to examine whether experience with examples facilitates or hinders participants' attempts to solve novel target problems. Our goal was to evaluate in detail the possible negative effects of examples in pictorial format suggested by earlier studies (Jansson & Smith, 1991; Purcell et al., 1993). In particular, two experiments were designed to examine the negative effects of pictorial examples explicitly depicting inappropriate solutions when participants naive to design tasks attempted to solve a number of design problems.

In contrast to previous research, our primary aim was to provide a thorough and comprehensive account of possible fixation effects due to pictorial examples through a combination of both quantitative and qualitative analyses. Quantitative analysis for both experiments included various fixation measures used in previous design-fixation studies (Purcell et al., 1993). Following the example of Chi, DeLeeuw, Chiu, and LaVancher (1989) and VanLehn (1998), the qualitative analysis included an analysis of verbal protocols obtained in Experiment 1 as participants were thinking aloud.

The present study differs from the Jansson and Smith (1991; see also Smith et al., 1993) and Purcell et al. (1993) studies in several ways. Earlier studies used group presentation, which may make it difficult to control the experimental situation; the experimenters had no way of knowing, for example, whether the students completely understood the problem and the restrictions. Moreover, because of group presentation, it is conceivable that students proposed many design solutions with insufficient explanations as to their proposed function. As a result, the designs might have been incorrectly interpreted and classified during data analysis. In contrast, the present experiments use a controlled laboratory paradigm in which participants were tested individually on the design problem-solving tasks.

In addition, the tasks used in most previous studies (Chi, Basok, et al., 1989; LeFevre & Dixon, 1986) all involved well-defined problems, that is, problems with one correct solution that the participant was expected to attain. Regarding the findings of LeFevre and Dixon (1986), in particular, it is important to examine whether there is a similar preference of participants for examples compared with instructions in ill-defined problems, that is, problems with no one specific correct solution. Finally, in the Jansson and Smith (1991) and Purcell et al. (1993) studies, each participant worked only on one problem; in contrast, the experiments assessed fixation by using more than one design problem.

Notwithstanding the present experiments' focus on design problem-solving tasks, the wide use of pictorial examples as instructional tools makes this study of broad potential significance to psychology and education. Although Jansson and Smith (1991) and Purcell et al. (1993) provided evidence for the occurrence of fixation specifically in design students and professional engineers, fixation from pictorial examples might be a more general problem-solving phenomenon, one that affects both design experts and participants naive to design tasks. If fixation due to example designs occurs irrespective of the individual's area of expertise, it may reflect a broader cognitive phenomenon, the implications of which are critical for learning and instruction, given the wide use of pictorial examples in a variety of educational settings (e.g., Lim & Moore, 2002). A variation of Jansson and Smith's (1991) experiment was therefore undertaken to determine whether fixation occurs in a laboratory design problem-solving situation with participants naive to design tasks.

### Experiment 1

This experiment examined whether the inclusion of example designs depicting inappropriate solutions—the problematic aspects of which are explicitly signified and described to the participants—negatively influences performance on design problem solving. We tested three conditions: (a) control (standard instructions), (b) fixation (inclusion of a problematic example, accompanied by description of its elements, including problematic elements), and (c) defixation (inclusion of a problematic example, accompanied by instructions to avoid using its problematic elements). On the basis of the results of Jansson and Smith (1991), we hypothesized that elements of the example designs would be more frequent in solutions in the fixation condition relative to the control condition and that this effect would not be diminished in the defixation condition, in which there were specific instructions to avoid the use of those elements.

For the qualitative assessment of participants' verbal protocols, an analysis similar to that of VanLehn (1998) was adopted. VanLehn found that less reference or even absence of reference to the examples was linked to more successful problem-solving performance. We provide an analysis of the (a) purpose of and (b) content of participants' references to pictorial examples during design problem solving. That is, we categorized participants' motivation for reference to the examples given.<sup>1</sup> On the basis of VanLehn's (1998) findings and the evidence provided in the design fixation literature (Jansson & Smith, 1991; Purcell & Gero, 1996; Purcell et al., 1993), we predicted that references to the example would be more frequent in the fixation condition, in

which participants should follow the example significantly more compared with the other two conditions.

### Method

#### Participants

Eighty-nine Temple University undergraduates (20 men; mean age 22.3 years) participated in this study as partial fulfillment of a requirement for introductory psychology; each participant was randomly assigned to one of the three conditions.

#### Materials

Three practical design problems were used: the bike rack problem and the coffee cup problem from Jansson and Smith (1991, pp. 5–8; see Appendix), as well as a similar problem taken from an industrial design class. The last problem (designing a container for cream cheese) was ultimately removed from the analysis because the example design provided appeared to be unclear to participants and the pictorial example was of inferior quality relative to the other two problems, thus frequently generating confusion. For the bike rack and coffee cup problems, the problem instructions, the pictorial examples and the descriptions of their problematic elements, and the defixation instructions were the same as those used by Jansson and Smith.

#### Design and Procedure

There were three conditions. The control condition ( $n = 30$ ) was presented only with the instructions for each problem. The fixation condition ( $n = 30$ ) was also presented with an example design accompanied by a short description of its problematic features. The defixation condition ( $n = 29$ ) was, in addition, specifically instructed to avoid using in the solutions certain elements of the example design. The order of the problems was counterbalanced. The problem instructions and the example designs are provided in the Appendix.

Each participant was tested individually. All sessions were videotaped with the participants' consent. Participants were informed that they would be solving three problems concerning flaws with everyday products. While attempting to solve each problem, participants were asked to perform three activities intended to produce a record of their solutions: (a) read aloud the problem instructions to ensure that they had indeed read and understood the problems, (b) show work on paper by drawing as many designs as they could and writing short comments with each, and (c) think aloud during problem solving. Verbal protocols have been widely used in problem-solving studies to provide a comprehensive record of participants' cognitive processes while solving different types of problems. Concurrent verbalization does not seem to interfere with participants' solution processes (although see Nisbett & Wilson, 1977), and experimental evidence suggests that verbalization does not negatively influence performance in problem-solving tasks (for a review, see Ericsson & Simon, 1993; see also Bloom & Keil, 2001; Dominowski, 1998; Reisberg, 2000; Taylor & Dionne, 2000). The instructions for verbalization were adapted from Perkins (1981, p. 33; Fleck & Weisberg, 2004):

While solving the problems you will be encouraged to think aloud. When thinking aloud you should do the following: Say whatever's on your mind. Do not hold back hunches, guesses, wild ideas, images, plans or goals. Speak as continuously as possible. Try to say something at least once every five seconds. Speak audibly. Watch for your

<sup>1</sup> The content of the reference to the examples was also measured quantitatively, with respect to the elements of the examples that participants reproduced in their designs.

voice dropping as you become involved. Do not worry about complete sentences or eloquence. Do not over explain or justify. Analyze no more than you would normally. Do not elaborate on past events. Get into the pattern of saying what you are thinking about now, not of thinking for a while and then describing your thoughts. Though the experimenter is present you are not talking to the experimenter. Instead, you are to perform this task as if you are talking aloud to yourself.

Prior to the experimental tasks, each participant was given a training problem for 2 min (the *two-string problem*) to familiarize him or her with the experimental procedure. Thirteen minutes were given for each experimental problem, and students were encouraged to continue working until the entire time had elapsed. Experimenter intervention was kept as minimal and as neutral as possible. Examples of possible interventions are as follows: (a) clarification (e.g., “Do you understand what the problem is here?”), (b) demonstration (e.g., “Could you draw that?”), and (c) encouragement (e.g., “You are doing great,” “Keep on working,” “These are some pretty good ideas”). After completing the problems, participants were administered a short questionnaire similar to one used by Jansson and Smith (1991). This was intended to detect familiarity with the experimental task. Participants were then debriefed about the purpose of the experiment.

*Quantitative Analysis*

*Problem Analysis: Measures of Design Fixation*

The aim of our initial analysis was to evaluate the presence of fixation quantitatively (see also Chryssikou & Weisberg, 2003). To assess the occurrence of fixation, we used a measurement procedure similar to that of Purcell et al. (1993). For both problems, the

measures of design fixation included (a) measures of similarity (direct, reproductive, and analogical), (b) measures of reproduction of intentional flaws, and (c) measures of unintentional flaws. *Direct physical similarity* occurred when participants directly copied the example design. *Reproductive similarity* occurred when participants used parts of the example or configurations of parts that could be recognized. *Analogical similarity* occurred when participants used design principles in the example designs without using the actual physical form of the example. *Intentional flaws* occurred when participants reproduced flaws that we had deliberately introduced in the example designs and included in the accompanying description of each design. Finally, *unintentional flaws* occurred when participants reproduced flaws in the example design that were not explicitly pointed out in the instructions but that the students detected. That is, during the experiment, students sometimes mentioned problematic aspects of the example designs that were not included in the description accompanying each of them and then included those features in their own solution. Problematic features that were mentioned by at least one third of the students were coded as unintentional flaws. Table 1 provides definitions and examples of the specific fixation measures used for each problem.

*Protocol Analysis and Scoring*

Each problem was analyzed from the written protocols and the videotapes. The verbalizations from the videotapes were used to clarify ambiguous parts in the designs, as the students provided a

Table 1  
*Fixation Measures: Definitions and Scoring for Each Problem*

Measure	Definition	Scoring
The bike rack problem		
Direct physical similarity	Same shapes, patterns, type of car, roof of the car, tire railings, suction cups, and attachment mechanism similar to the example design.	0/1
Reproductive similarity	(1) Use of the top of the car; (2) use of suction cups; (3) use of tire railings; (4) use of the same type of sketch angle (e.g., three-dimensional design); (5) use of the same type of car roof sketch pattern (e.g., shape, double lines).	0–5
Analogical similarity	(1) Alternative ways to attach the rack to the car, instead of suction cups (e.g., magnets); (2) alternative ways to secure the bikes on the rack, instead of tire railings (e.g., separate compartments).	0–2
Intentional flaws	The generation of a top-mount design (difficulty of mounting the rack on the car and the bikes on the rack).	0/1
Unintentional flaws	(1) The use of suction cups (not secure enough to hold a rack on the roof of the car); (2) placing the bike on the rack in a vertical position (not steady, harder to mount, increases car height).	0–2
The coffee cup problem		
Direct physical similarity	Same shapes, patterns, and angle as the example design, as well as a styrofoam cup, with a mouthpiece and a bent straw.	0/1
Reproductive similarity	(1) Use of straw; (2) use of mouthpiece (i.e., an extension of the cup lid); (3) use of overflow device inside the cup (i.e., bent straw); (4) use of the same type of sketch angle (i.e., triangular cup, 90° angle for the tipping cup); (5) use of the same type of sketch pattern (i.e., a double layer cup).	0–5
Analogical similarity	(1) Alternative ways to prevent overflowing, instead of the bent straw (e.g., reservoir); (2) alternative ways to insulate the cup (e.g., thermos solution).	0–2
Intentional flaws	(1) The use of a straw that would leak; (2) the styrofoam, squeezable cup; (3) the hot liquid coming uncooled from the straw that would burn the user’s mouth.	0–3
Unintentional flaws	(1) A base of the cup that is narrower than the top, which might lead to tipping over; (2) a straw that is permanently attached to the lid, making it not flexible during use.	0–2

Table 2  
Means and Standard Deviations for Fixation Measures by Problem

Fixation measure	The bike rack problem						The coffee cup problem					
	CC ( <i>n</i> = 30)		FC ( <i>n</i> = 30)		DFC ( <i>n</i> = 29)		CC ( <i>n</i> = 30)		FC ( <i>n</i> = 30)		DFC ( <i>n</i> = 29)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Total designs	2.67	1.27	2.73	1.48	2.55	1.35	2.87	1.22	2.93	1.17	2.45	1.30
Time (s) to begin first design	47.97	51.15	65.57	58.08	82.41	78.86	<u>32.37</u>	23.52	51.33	40.47	57.83	46.82
Reproductive similarity	<u>0.13</u>	0.12	<u>0.31</u>	0.19	<u>0.04</u>	0.09	0.11	0.10	<u>0.28</u>	0.19	0.15	0.11
Analogical similarity	0.08	0.15	<u>0.28</u>	0.27	0.08	0.15	0.15	0.19	0.20	0.22	0.17	0.19
Intentional flaws	0.48	0.29	<u>0.65</u>	0.38	<u>0.02</u>	0.08	0.22	0.16	<u>0.37</u>	0.24	0.23	0.19
Unintentional flaws	<u>0.17</u>	0.15	<u>0.42</u>	0.32	<u>0.01</u>	0.02	0.06	0.11	<u>0.36</u>	0.34	0.11	0.19

Note. Underlined means data indicate a significant difference between the compared groups (see Table 3 for details). CC = control condition; FC = fixation condition; DFC = defixation condition.

detailed explanation of their solutions. Each solution was analyzed separately. Solutions were scored for the inclusion of problematic features in the designs; each solution received a score for each of the five fixation categories presented in the previous section: (a) direct similarity, (b) reproductive similarity, (c) analogical similarity, (d) intentional flaws, and (e) unintentional flaws (see Table 1). Measures of the time taken to begin the first solution (i.e., time between completing the instructions and starting the first design) as well as the time needed to complete each solution were also calculated. After one of the researchers coded the protocols in their entirety, an independent rater, blind to the aims of the experiment, was trained on the coding system and coded 30% of the protocols. The ratings of the independent rater were compared with the initial ratings, separately for each of the five fixation measures. The average interrater reliability (Pearson's correlation) across the five fixation measures was .87 for both problems; any disagreements among the coders were resolved through discussion. These findings support the use of this coding system as a reliable measure of design fixation.

### Results and Discussion

To examine the differences for each problem among the three conditions on the five fixation measures, we used a contrast-based analysis of variance (ANOVA) approach. We performed an analysis of the data on the proportion of solutions that showed evidence of fixation on each of the five measures, by participant, for each problem. The scores of each participant for each of the five measures, for each solution produced, were added and then divided by the highest possible fixation score that the participant could have obtained on that measure for the total number of solutions generated.<sup>2</sup> Exploratory data analysis revealed, in certain cases, violations of normality and homogeneity of variance; thus, some of the reported values do not assume equal variances among the compared groups.

For the bike rack problem, although direct physical similarity was negligible across conditions (i.e., only 1 participant directly copied the example design), the differences for the remaining fixation measures were significant (see Tables 2 and 3). That is, relative to the control condition, the fixation condition reproduced significantly more elements of the example design, more analogically similar solutions, and more unintentional flaws; the differ-

ence for the generation of the intentional flaws was only marginally significant. Relative to the defixation condition, the fixation condition generated significantly more elements of the example design and more solutions that were analogically similar to it and included more of the intentional and unintentional flaws in the designs. Finally, the defixation condition reproduced fewer elements of the example designs and integrated fewer of the intentional and unintentional flaws than the control condition. The difference between the defixation and control conditions for the analogical similarity measures did not reach statistical significance.

For the coffee cup problem, the measures of direct physical similarity did not reveal significant differences among the three conditions (see Tables 2 and 3). Relative to the control condition, the fixation condition reproduced more elements of the example design and included in the solutions more intentional and unintentional flaws. Although the differences for the analogical similarity measures were in the expected direction, they did not reach significance. Relative to the defixation condition, participants in the fixation condition reproduced significantly more elements of the example design and included more intentional and unintentional flaws in their designs. In contrast, the differences were not significant for the measures of analogical similarity. Finally, between the control condition and the defixation condition, none of the differences reached significance. Further analyses by individual solutions for both problems supported the results of the overall analysis of the problems.

In conclusion, quantitative analysis indicated that the inclusion of the example design did produce strong fixation effects, replicating previous research. However, contrary to Jansson and Smith's (1991) original findings, specific instructions to avoid using the features presented in the examples eliminated the fixation effect.<sup>3</sup>

<sup>2</sup> Proportions were preferred to means in this case, as the variability of the data would significantly inflate the experiment-wise error rate.

<sup>3</sup> Even though the efficiency of participants' ideas was not systematically assessed in the present study, it should be noted that participants in the defixation condition did not avoid fixation by generating solutions of lower quality relative to participants in the control condition.

Table 3  
*Analysis of Variance: Fixation Measures by Problem Collapsed Across Solutions*

Condition	Reproductive similarity			Analogical similarity			Intentional flaws			Unintentional flaws		
	<i>df</i>	<i>F</i>	$\omega^2$	<i>df</i>	<i>F</i>	$\omega^2$	<i>df</i>	<i>F</i>	$\omega^2$	<i>df</i>	<i>F</i>	$\omega^2$
The bike rack problem												
CC × FC	49.76	19.33**	.06	44.71	13.06**	.04	54.36	3.92	.01	41.58	15.89**	.03
FC × DFC	42.67	49.04**	.09	45.03	13.22**	.04	31.39	80.68**	.04	29.35	51.64**	.06
CC × DFC	54.06	10.00*	.02	56.93	<0.01	.01	33.04	70.56**	.03	30.52	33.24**	.02
The coffee cup problem												
CC × FC	42.24	19.58**	.07	86.00	0.77	.01	86.00	8.61*	.03	34.90	21.28**	.04
FC × DFC	48.29	10.62*	.06	86.00	0.31	.01	86.00	7.69*	.03	46.25	12.74*	.03
CC × DFC	53.68	1.30	.01	86.00	0.10	.01	86.00	0.02	.01	43.89	1.20	.01

Note. CC = control condition; FC = fixation condition; DFC = defixation condition.  
 \*  $p \leq .01$ . \*\*  $p \leq .001$ .

*Qualitative Analysis*

*Verbal Protocol Analysis: Objectives*

If the presence of pictorial examples that provide inappropriate information indeed induces fixation, as our quantitative analysis suggests, then one would predict that participants in the fixation condition would tend to follow the example significantly more than in the other two conditions.

*Protocol Analysis and Coding*

The protocol analysis assessed whether participants' references to the examples differed across the three conditions on the two design problem-solving tasks. Transcripts were obtained from the videotapes and then were segmented into statements, with a statement defined as a unit of information related to participants' work on a specific component of a solution (e.g., a coffee cup's shape). Two protocols were dropped from the bike rack problem (one from the control condition and one from the fixation condition) because of sound-recording problems, resulting in a total of 176 transcripts.

Participants' solution patterns were analyzed from the written transcripts and the videotapes. Each statement was analyzed separately. The maximum number of statements per participant for the bike rack problem was 53, and for the coffee cup problem it was 32. A modification of the coding system of VanLehn (1998) was used. The categories of the coding system and their definitions follow.

1. *Using the problem instructions to implement a step.* The participant revisited the instructions before proceeding toward the solution to the problem. The participant did not reach an impasse before consulting the instructions; he or she neither paused nor expressed frustration. The participant may have used the instructions (a) to implement a step for the first solution, (b) to proceed with subsequent solutions after having generated one or more solutions, or (c) to implement a step with respect to specific parts of a solution.

2. *Using the example to implement a step.* The participant used the example to obtain technical details before consulting the in-

structions. The participant did not reach an impasse before consulting the example; he or she neither paused nor expressed frustration. The participant may have used the example (a) to implement a step for the first solution, (b) to proceed with subsequent solutions after having generated one or more solutions, or (c) to implement a step relating to specific parts of a solution. The participant referred to the same design principles exhibited in the example design without using the actual physical form of the example design. In particular, analogous features would include the following for the bike rack problem:

1. Alternative ways to attach the rack to the car, instead of suction cups (e.g., magnets). The analogous solutions should represent the general idea of attaching the rack on the car.
2. Alternative ways to secure the bikes on the rack, instead of tire railings (e.g., separate compartments or shelves). The analogous ideas should represent the general design approach of separating and locking the bikes on the rack.

For the coffee cup problem, analogous features would include the following:

1. Alternative ways to prevent overflowing, instead of the bent straw (e.g., reservoir). The analogous solutions should represent the general idea of preventing spillage by allowing overflow inside the cup.
2. Alternative ways to insulate the cup (e.g., thermos solution). The analogous ideas should represent the general design approach of preserving the temperature of the liquid with multiple layers of material.

3. *Using the problem instructions to repair an impasse.* The participant had a specific goal, could not achieve it, and referred to the instructions. Before referring to the instructions, the participant must have reached an impasse—that is, he or she must have paused or expressed difficulty or frustration in proceeding with (a) a new solution or (b) specific parts of a solution.

4. *Using the example to repair an impasse.* The participant had a specific goal, could not achieve it, and referred to the example. Before referring to the example, the participant must have reached an impasse—that is, he or she must have paused or expressed difficulty or frustration to proceed with (a) a new solution or (b) specific parts of a solution.

5. *Using the instructions to check an action or a decision.* The participant produced the solution and then went back to the instructions to examine the effectiveness of the proposed solution. The participant must have already generated a solution before checking an action or decision; he or she revisited the instructions to evaluate whether the proposed solution met the needs of the problem.

6. *Using the example to check an action or a decision.* The participant produced the solution and then went back to the example to examine the effectiveness of the proposed solution. The participant must have already generated a solution before checking an action or decision; he or she revisited the example to evaluate whether the proposed solution met the needs of the problem and/or improved or deviated from the example design.

7. *Following the example.* The participant finished working on a part of the problem, looked at the example, and copied it directly. There was an explicit reference to and/or use of (a) specific elements depicted in the example design and/or (b) specific elements included in the accompanying description of the example design. Possible elements that could be reproduced from the example design for the bike rack problem were the following:

1. Use of the top of the car (i.e., roof)
2. Use of suction cups
3. Use of tire railings (i.e., grooves into which the tires fit)
4. Use of the same type of attachment mechanism as the one in the example design (i.e., vinyl-coated hook attached to the seat tube of the bike hook, tightened down by hand with a wing nut)

Possible elements that could be reproduced for the coffee cup problem were as follows:

1. Use of straw
2. Use of mouthpiece (i.e., an extension of the cup lid)
3. Use of overflow device inside the cup (i.e., bent straw)
4. Use of the same type of sketch angle (i.e., triangular cup, 90° angle for the tipping cup)

8. *Personal reference.* The participant referred neither to the problem instructions nor to the example. He or she generated a solution entirely on his or her own or with reference to personal experience or to one or more of his or her previous designs from the study.

9. *Response to experimenter's intervention/interaction with experimenter.* The participant provided a solution or part of a solution or elaborated on a solution as a result of a question or comment from the experimenter. The experimenter might have intervened independently or after the participant's request (i.e., the participant asked the experimenter directly for additional information, explanation, or elaboration on the problem instructions).

10. *Miscellaneous events.* The miscellaneous events category was used for any events in which the participant's references were ambiguous and/or could not be classified under any other category.

Two trained independent raters blind to the experimental design coded the data. Ratings were compared with each other for all 10 coding categories, separately for each problem. Interrater reliability (Cramer's  $V$ ) reached .94 for the bike rack problem and .95 for the coffee cup problem. Any differences among the raters were resolved in conference. We randomly selected the coding of one rater for the statistical analyses.

## Results and Discussion

We first assessed whether there were differences in the frequency of statements across the three conditions, with a significance level of .05. For the bike rack problem, the mean number of statements for the control, fixation, and defixation conditions were 21.34 ( $SD = 6.79$ ), 19.86 ( $SD = 6.21$ ), and 27.66 ( $SD = 8.45$ ), respectively. Planned contrasts revealed no differences between the control and fixation conditions,  $F(55.55, 86) = 0.75, p = .39$ . In contrast, the defixation condition had significantly more statements than both the control condition,  $F(53.54, 86) = 9.82, p < .01$ , and the fixation condition,  $F(51.42, 86) = 16.02, p < .01$ . For the coffee cup problem, the means for the control, fixation, and defixation conditions were 18.97 ( $SD = 5.68$ ), 19.10 ( $SD = 6.43$ ), and 18.17 ( $SD = 6.41$ ), respectively. Planned contrast comparisons revealed no differences between the control and fixation conditions,  $F(57.14, 88) = 0.01, p = .93$ , and no differences between the defixation condition and the control condition,  $F(55.67, 88) = 0.25, p = .62$ , or the fixation condition,  $F(56.94, 88) = 0.31, p = .58$ . Because of the unequal number of statements among protocols, we calculated the percentage of responses falling within each category for each problem. To examine the differences among the three experimental conditions, we performed a series of planned contrast ANOVA comparisons with a significance level of .002 (with a Bonferroni correction). The conditions that we compared on the 10 transfer measures (for each problem separately) were (a) control versus fixation, (b) fixation versus defixation, and (c) control versus defixation. The mean percentages, standard deviations, and significant comparisons for each category by problem are presented in Table 4. Similar to the quantitative results, exploratory data analysis revealed violations of normality and homogeneity of variance; thus, the reported values do not assume equal variances among the compared groups.

For the bike rack problem, relative to the control condition, the participants in the defixation condition used the instructions significantly less frequently to implement a step in the problem-solving process. In accordance with the original predictions, the participants in the fixation condition followed the example significantly more than those in both the control and the defixation

Table 4  
Mean Percentages and Standard Deviations for Verbal Protocol Coding Categories by Problem

Coding categories	CC		FC		DFC	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
The bike rack problem ( <i>n</i> = 87)						
1. Using the problem instructions to implement a step	18.63	14.40	13.09	12.00	5.31	6.10
2. Using the example to implement a step	0.00	0.00	13.50	11.91	7.21	6.42
3. Using the problem instructions to repair an impasse	1.38	3.06	1.06	2.46	0.44	1.33
4. Using the example to repair an impasse	0.00	0.00	1.50	3.18	0.63	2.04
5. Using the instructions to check an action or a decision	10.45	9.28	8.13	7.65	4.52	5.52
6. Using the example to check an action or a decision	0.00	0.00	0.85	2.62	1.79	2.63
7. Following the example	0.00	0.00	10.15	11.66	0.92	2.31
8. Personal reference	43.27	19.60	30.44	17.34	37.10	16.87
9. Response to experimenter's intervention/interaction with the experimenter	17.26	19.36	16.60	17.20	36.58	20.84
10. Miscellaneous events	6.58	6.17	4.57	4.92	7.31	8.08
The coffee cup problem ( <i>n</i> = 89)						
1. Using the problem instructions to implement a step	27.95	14.59	16.84	15.49	14.42	11.41
2. Using the example to implement a step	0.00	0.00	9.04	7.07	9.16	8.80
3. Using the problem instructions to repair an impasse	2.30	5.60	0.00	0.00	1.05	4.72
4. Using the example to repair an impasse	0.00	0.00	0.60	2.41	0.73	2.40
5. Using the instructions to check an action or a decision	15.60	11.99	8.28	6.79	9.35	8.97
6. Using the example to check an action or a decision	0.13	0.73	0.54	2.08	2.86	4.46
7. Following the example	0.00	0.00	13.00	12.49	2.08	4.72
8. Personal reference	33.74	19.55	33.65	18.26	28.94	15.62
9. Response to experimenter's intervention/interaction with the experimenter	9.04	12.14	10.72	11.49	25.39	16.01
10. Miscellaneous events	8.04	10.13	5.88	5.80	4.19	5.61

Note. CC = control condition; FC = fixation condition; DFC = defixation condition.

conditions.<sup>4</sup> Finally, participants in the defixation condition engaged more in interaction with the experimenter compared with participants in both the control and the fixation conditions (see Table 5 for details). This difference is most likely attributed to the fact that the additional instruction in the defixation condition to avoid using elements of the example design seemed to have increased the difficulty of the problem; thus, participants interacted with the experimenter more frequently for comments related to problem difficulty or clarifications as to what they were allowed to do. None of the other comparisons among conditions reached significance. It should be noted that, for the significant comparisons, the measures of effect size were relatively large, ranging from  $\omega^2 = .10$  to  $\omega^2 = .25$  (see Table 5).

Similar results were obtained for the coffee cup problem. Compared with the control condition, the participants in the defixation condition used the instructions significantly less frequently than the example to implement a step in the problem-solving process. Participants in the fixation condition, in line with initial hypotheses, followed the example significantly more relative to those in both the control and the defixation conditions. Finally, participants in the defixation condition engaged more in interaction with the experimenter relative to participants in the fixation condition (see Table 6 for details). None of the other comparisons among conditions reached significance. Again, for the significant comparisons, the measures of effect size were relatively large, ranging from  $\omega^2 = .13$  to  $\omega^2 = .31$  (see Table 6).

Regarding the use of examples versus the use of instructions in the fixation condition, participants solving the bike rack problem did not differ in their use of examples versus instructions to

implement a step,  $t(28) = 0.05$ ,  $p = .96$ , or to overcome an impasse,  $t(28) = -0.89$ ,  $p = .38$ . In contrast, they showed a significant preference for the instructions relative to the example when evaluating their actions or decisions,  $t(28) = 4.68$ ,  $p < .01$ . Also, their personal references were significantly more frequent than their attempts to follow the example,  $t(28) = -6.05$ ,  $p < .01$ . For the coffee cup problem, participants referred significantly more to the instructions than to the example to implement a step,  $t(29) = 2.36$ ,  $p = .03$ . However, their references to the instructions versus the example did not differ when they were overcoming an impasse,  $t(29) = -1.28$ ,  $p = .21$ . In line with the results from the bike rack problem and contrary to previous findings (LeFevre & Dixon, 1986; Pirolli & Anderson, 1985), participants showed an overwhelming preference for the instructions relative to the example when evaluating their actions or decisions,  $t(29) = 5.42$ ,  $p < .01$ . Finally, personal references were significantly more frequent than attempts to follow the example,  $t(29) = -4.01$ ,  $p < .01$ .

<sup>4</sup> One might question the appropriateness of comparing the fixation and defixation conditions with the control condition with respect to Categories 2, 4, 6, and 7, which pertain to references to the example. Obviously, the control group was not presented with an example design; therefore, the frequency of participants' references in these cases was zero. Nonetheless, our aim was to examine whether the presence of an example in addition to the instructions for the fixation and defixation conditions would have an effect compared with a control condition that was not presented with an example. It might have been the case that participants in these two conditions, even with the pictorial example in front of them, did not refer to that example.



Table 5  
Analysis of Variance: Percentage of Responses by Category for the Bike Rack Problem

Condition	1. Instructions to implement a step			2. Example to implement a step			3. Instructions to repair an impasse			4. Example to repair an impasse			5. Instructions to check an action or a decision		
	df	F	$\omega^2$	df	F	$\omega^2$	df	F	$\omega^2$	df	F	$\omega^2$	df	F	$\omega^2$
CC × FC	54.23	2.53	.02	28.00	37.27	.34	53.54	0.20	.02	28.00	6.49	.07	54.05	1.09	< .01
FC × DFC	41.55	9.71	.06	43.02	6.26	.07	43.10	1.41	< .01	47.78	1.57	.02	50.93	4.23	.02
CC × DFC	37.72	21.05***	.18	28.00	36.58	.09	38.24	2.30	.01	28.00	2.72	< .01	45.63	8.75	.08

Note.  $n = 87$ . CC = control condition; FC = fixation condition; DFC = defixation condition.  
\*\*\*  $p < .002$  (with a Bonferroni correction).

Overall, the verbal protocol analysis revealed that participants referred to the problem instructions but that they tended to follow the examples.

verbalize, to examine potential effects of fixation to example designs when participants were not interacting at all with the experimenter.

Experiment 2

Method

The results obtained from the quantitative and qualitative analyses of Experiment 1 clearly suggest that (a) although participants consulted the problem instructions, they tended to follow the examples even when the examples included inappropriate elements, and (b) contrary to previous studies (e.g., Jansson & Smith, 1991), fixation effects can be diminished with the use of defixating instructions. In response to the results obtained in Experiment 1, however, it could be argued that the concurrent verbalization procedure might have interfered with the problem-solving process, particularly for the defixation condition, thus making participants more aware of the problematic elements of the example designs and of the restrictions to avoid reproducing them. Recent findings by Hamel and Elshout (2000; see also Ryan & Schooler, 1998; Schooler & Melcher, 1995), for example, suggest that concurrent verbalization may assist participants in avoiding making mistakes in problem solving. Furthermore, as supported by the qualitative analysis, a significant proportion of participants in Experiment 1 engaged in interaction with the experimenter, mostly in the defixation condition. These interactions, in addition to the experimenter's interventions (e.g., encouragement) during the experimental sessions, might have influenced participants' performance apropos conforming to the examples presented. To address this concern, we conducted a second experiment in which participants did not

Participants

Sixty Temple University undergraduates (12 men; mean age 19.13 years) participated in this study as partial fulfillment of a requirement for introductory psychology; each participant was randomly assigned to one of three conditions.

Materials

The two problems from Experiment 1 were used (see Appendix).

Design and Procedure

The design and procedure were the same as in Experiment 1, except that participants did not verbalize and the experimenter did not interact with them in any way. Each of the three conditions (control, fixation, and defixation) included 20 participants. Two protocols for the bike rack problem in the control condition had to be excluded from the analysis because the participants did not comprehend the instructions.

Protocol Analysis and Coding

The aim of the statistical analysis in Experiment 2 was to evaluate quantitatively the presence of fixation using the design fixation measurement procedure implemented for the quantitative analysis in Experiment 1. Each problem was analyzed from participants' written protocols. Solutions were

Table 6  
Analysis of Variance: Percentage of Responses by Category for the Coffee Cup Problem

Condition	1. Instructions to implement a step			2. Example to implement a step			3. Instructions to repair an impasse			4. Example to repair an impasse			5. Instructions to check an action or a decision		
	df	F	$\omega^2$	df	F	$\omega^2$	df	F	$\omega^2$	df	F	$\omega^2$	df	F	$\omega^2$
CC × FC	57.79	8.19	.08	29.00	49.07***	.23	29.00	5.07	.04	29.00	1.84	< .01	45.85	8.47	.08
FC × DFC	53.31	0.47	< .01	53.68	0.00	< .01	28.00	1.44	< .01	56.96	0.05	.01	52.13	0.27	.01
CC × DFC	54.65	15.82***	.13	28.00	31.48***	.23	55.98	0.86	< .01	28.00	2.73	.01	53.68	5.16	.06

Note.  $n = 89$ . CC = control condition; FC = fixation condition, DFC = defixation condition.  
\*\*\*  $p < .002$  (with a Bonferroni correction).

6. Example to check an action or a decision			7. Following the example			8. Personal reference			9. Response to the experimenter's intervention/interaction with the experimenter			10. Miscellaneous events		
<i>df</i>	<i>F</i>	$\omega^2$	<i>df</i>	<i>F</i>	$\omega^2$	<i>df</i>	<i>F</i>	$\omega^2$	<i>df</i>	<i>F</i>	$\omega^2$	<i>df</i>	<i>F</i>	$\omega^2$
28.00	3.01	.02	28.00	21.96***	.25	55.18	6.97	.07	55.24	0.06	.01	53.34	1.87	< .01
56.00	1.86	.02	30.20	17.44***	.21	55.96	2.20	.01	54.06	15.86***	.14	46.24	2.43	.02
28.00	13.34***	.10	28.00	4.68	.01	54.79	1.65	.01	55.70	12.75***	.13	52.38	0.15	.01

analyzed separately and were scored for the inclusion of problematic features in the designs; each solution received a score for each of the five fixation categories presented in Experiment 1: (a) direct similarity, (b) reproductive similarity, (c) analogical similarity, (d) intentional flaws, and (e) unintentional flaws. After one of the researchers coded the protocols in their entirety, an independent rater, blind to the aims of the experiment, was trained on the coding system and coded 30% of the protocols. The ratings of the independent rater were compared with the initial ratings, separately for each of the five fixation measures. The average interrater reliability (Pearson's correlation) across the five fixation measures was .85 for both problems; any disagreements among the coders were resolved through discussion.

*Results and Discussion*

We performed planned ANOVA contrast comparisons modeled after the quantitative analysis in Experiment 1. Exploratory data analysis revealed violations of normality and homogeneity of variance. Thus, the reported values do not assume equal variances among the compared groups. Overall, the findings replicate those obtained in Experiment 1 (see Table 7). For the bike rack problem, relative to the control condition, the fixation condition reproduced significantly more elements of the example design,  $F(25.48, 55.00) = 54.52, p < .01$ , and more unintentional flaws,  $F(32.92, 55.00) = 12.54, p < .01$ ; the difference for the generation of the intentional flaws was not significant. Relative to the defixation condition, participants in the fixation condition generated significantly more elements of the example design,  $F(37.99, 55.00) = 54.52, p < .01$ , and included more of the intentional,  $F(36.80, 55) = 10.78, p < .01$ , and unintentional,  $F(33.10, 55.00) = 19.61,$

$p < .01$ , flaws in their designs. Finally, the differences between the defixation and control conditions did not reach statistical significance.

For the coffee cup problem, the findings replicate those of Experiment 1. Relative to the control condition, participants in the fixation condition reproduced more elements of the example design,  $F(23.52, 57.00) = 24.63, p < .01$ , and included in their solutions more intentional,  $F(31.95, 57.00) = 15.73, p < .01$ , and unintentional,  $F(28.29, 57.00) = 21.01, p < .01$ , flaws, whereas the difference for the analogical similarity measures did not reach significance. Relative to the defixation condition, participants in the fixation condition generated significantly more elements of the example design,  $F(23.98, 57.00) = 24.84, p < .01$ , and included more intentional,  $F(37.94, 57.00) = 5.84, p < .05$ , and unintentional,  $F(34.15, 57.00) = 11.79, p < .01$ , flaws in their designs. For the measures of analogical similarity, the differences were not significant. Finally, between the control condition and the defixation condition, similar to the results of Experiment 1, none of the differences reached significance. The results of Experiment 2 indicate that concurrent verbalization and interaction with the experimenter did not account for the fixation effects obtained in Experiment 1. Overall, in Experiment 2, the inclusion of the example design produced strong fixation effects; however, explicit instructions to avoid using the features presented in the examples also eliminated the fixation effect. Thus, concurrent verbalization during problem solving does not account for the effect of the defixating instructions.

6. Example to check an action or a decision			7. Following the example			8. Personal reference			9. Response to the experimenter's intervention/interaction with the experimenter			10. Miscellaneous events		
<i>df</i>	<i>F</i>	$\omega^2$	<i>df</i>	<i>F</i>	$\omega^2$	<i>df</i>	<i>F</i>	$\omega^2$	<i>df</i>	<i>F</i>	$\omega^2$	<i>df</i>	<i>F</i>	$\omega^2$
36.08	1.03	.01	29.00	32.51***	.31	57.73	0.00	.01	57.82	0.30	.07	46.17	1.03	< .01
39.30	6.47	.09	37.36	20.01***	.21	56.18	1.13	< .01	50.68	16.26***	.15	57.00	1.30	< .01
29.45	10.54	.12	28.00	5.61	< .01	55.07	1.09	< .01	52.21	19.44	.19	45.57	3.29	.03

Table 7  
Means and Standard Deviations for Fixation Measures by Problem for Experiment 2

Fixation measure	The bike rack problem						The coffee cup problem					
	CC ( <i>n</i> = 18)		FC ( <i>n</i> = 20)		DFC ( <i>n</i> = 20)		CC ( <i>n</i> = 20)		FC ( <i>n</i> = 20)		DFC ( <i>n</i> = 20)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Total designs	1.83	0.92	1.80	1.00	1.65	0.67	2.35	1.70	2.30	1.26	1.70	0.73
Reproductive similarity	0.12	0.09	<u>0.51</u>	0.22	0.15	0.21	0.07	0.09	<u>0.37</u>	0.25	0.06	0.09
Analogical similarity	0.16	0.28	<u>0.19</u>	0.32	0.21	0.33	0.20	0.22	<u>0.27</u>	0.28	<u>0.07</u>	0.14
Intentional flaws	0.56	0.40	<u>0.77</u>	0.39	0.33	0.47	0.09	0.14	<u>0.32</u>	0.22	0.15	0.21
Unintentional flaws	0.20	0.22	<u>0.52</u>	0.33	0.13	0.22	0.07	0.16	<u>0.43</u>	0.32	0.14	0.22

Note. Underlined means indicate significant difference between the compared groups. CC = control condition; FC = fixation condition; DFC = defixation condition.

### General Discussion

The main aim of this study was to examine whether the inclusion of examples with inappropriate elements, in addition to the instructions for a design problem, would produce fixation effects in students naive to design tasks. Contrary to suggestions by Ross and Kilbane (1997) and Sternberg and Ben-Zeev (2001), including examples with inappropriate solutions as instructional tools in problem solving, in fact, inhibited participants' performance. The results of our quantitative analyses from both experiments suggest that, even when participants do not have expertise in design, fixation emerges in a problem-solving task when pictorial examples are used. Most striking is that participants consistently reproduced elements of the example designs that were specifically described as problematic.

However, in contrast to earlier studies, instructions to avoid using those problematic features diminished the fixation effect of the pictorial material, and this result was also obtained when participants did not verbalize or interact with the experimenter. On most quantitative measures, contrary to Jansson and Smith (1991), the defixation condition was quite similar to the control condition rather than to the fixation condition. It should be noted that the length and specificity of the defixating instructions did not differ relative to the earlier study. In fact, in the present experiments, the pictorial examples, the descriptions of the examples, and the defixation instructions were the same as those used by Jansson and Smith (1991); thus, the absence of fixation in the defixation condition cannot be attributed to any differences in the instructions between the two studies. Conversely, in contrast to the group presentation used in the previous studies (Jansson & Smith, 1991; Purcell et al., 1993; Smith et al., 1993), we tested each participant individually, ensured that participants carefully read the instructions in their entirety, and clarified any ambiguities arising from the way the problems were phrased. As a result, it seems that when students completely comprehend the problems and the restrictions given, they are likely to follow the instructions and not fixate on the problematic elements of the pictorial examples. Thus, the lack of fixation effects in the defixation condition in the present studies is likely to have occurred as a result of the controlled laboratory paradigm under which our experiments were conducted.

With reference to LeFevre and Dixon's (1986) predictions regarding the effects of examples in ill-defined and novel tasks, our findings extend those of Smith et al. (1993). In particular, our

results suggest that it is possible to have negative transfer from pictorial examples in creative generation tasks, even in cases in which those examples are inappropriate for the solution to the target problem. In addition, LeFevre and Dixon (1986) argued that written instructions are processed superficially and, thus, participants may rely more on other sources of information. They predicted that in cases in which an ambiguous or poorly designed example may suggest an inappropriate procedure, "readers would be more likely to use an inappropriate procedure based on the example, rather than following the more accurate written instructions" (p. 29). However, according to the results of our verbal protocol analysis, participants seemed to refer to the task instructions regardless of their tendency to follow the example, particularly when evaluating their actions or decisions or when implementing novel steps. This finding could be related to Purcell et al.'s (1993) claim that the fixation observed from Jansson and Smith's (1991) examples was due to the examples' high complexity. It might be the case that participants in our study dealt with the complexity of the example designs by referring equally often to the problem instructions and to their personal experience.

VanLehn (1998) proposed an alternative explanation, according to which there are two ways participants may solve a problem that are independent of how people study examples. The first one is through rule-based reasoning, and the second is through case-based reasoning (CBR; cf. Kolodner, 1993). If participants avoid using CBR, then they will be more successful in solving problems. For VanLehn, participants who use CBR lose the opportunity to learn rules and, thus, are less successful solvers. Accordingly, we suggest that participants who reproduced elements of the example are likely to have followed CBR and were, therefore, significantly more fixated by the example.

In addition, several studies on the effects of transferring knowledge from various examples to novel problems identified factors that promote effective learning from worked-out examples. One of the factors that seems to be particularly beneficial has been defined as the *self-explanation effect* (Chi, Bassok, Lewis, Reimann, & Glaser, 1989; see also Reimann & Neubert, 2000; VanLehn, Jones, & Chi, 1992; Wright, 1981), which refers to the idiosyncratic ways individuals explain elements of the examples to themselves during problem solving. For example, VanLehn (1998) observed no difference in the number of self-explanations among successful and unsuccessful solvers. This finding parallels our result that the

number of personal references (see Category 8, Table 4) remained stable across conditions.

A possible account for fixation effects, in the present study and in others, is based on the phenomenon of *cryptomnesia* or *unconscious plagiarism*—that is, participants' tendency to reproduce involuntarily previously seen ideas, words, solutions to problems, or examples, with the belief that they are either entirely original or at least original within a given context (Brown & Murphy, 1989). Cryptomnesia has been studied in the context of implicit memory phenomena as an extreme instance of *source amnesia* (Schacter, 1987; Schacter, Harbluk, & McLachlan, 1984). In source amnesia, a person forgets the source from which the information was acquired without misperceiving that the information is original. Consistent with our findings, these studies have shown that participants seem particularly prone to source-attribution errors in creative generation tasks but are able to control these errors after appropriate instruction (e.g., Brown & Murphy, 1989; Marsh & Landau, 1995; Marsh, Landau, & Hicks, 1997). Furthermore, in relation to the findings presented in this study, Brown and Murphy observed similar levels of cryptomnesia regarding visually presented verbal information between participants who were tested in groups and those who were tested individually.

Findings from research on inadvertent plagiarism could provide an interesting explanation regarding participants' fixation to improper pictorial examples observed in this study. In a series of experiments, Marsh and Bower (1993), for example, showed that participants' tendency to plagiarize words increased as a function of task difficulty. In addition, Marsh et al. (1997) have argued that "given a demanding primary activity like solving a problem, people may not have enough resources, or, more likely, simply may be less inclined to monitor the source of the ideas that they are generating" (p. 887). In general, it could be the case that a creative generation task, such as a complex design problem, may impose high cognitive demands on the solver, thus interfering with participants' episodic registering of the instructions and the examples given. Thus, in their effort to generate a satisfactory solution, participants may be more prone to reproduce elements of those examples because of inadequate source monitoring of the problem-solving situation.

Regarding these findings, an interesting question is whether fixation effects would be as strong (or stronger) if there were a delay between the presentation of the instructions and examples and the actual problem-solving phase. Marsh and Bower (1993) previously found no effects of delay on unconscious plagiarism; as a result, we would not expect differences in fixation if there were a delay between the presentation of the examples and the creative generation task. In addition, in most cases in which pictorial examples are used as instructional tools, the example is physically in front of the student during problem solving. Therefore, the paradigm used in our experiments resembles more closely the way examples are presented in educational settings.

It should be noted that in this study we did not include any measures aimed at estimating possible differences among the participants in factors that might be related to problem-solving performance. Our results suggest that individual differences in the use of examples are less important than the fixation or defixation instructions in influencing the occurrence of fixation. Nonetheless, it would be valuable if future experimental assessments of negative transfer provided some measures of individual differences (e.g.,

verbal and quantitative SAT scores). In addition, participants could be asked to perform tasks intended to estimate individual differences in the manipulation of items in pictorial format, such as the Paper Folding Test or the Elaboration Test (Ekstrom, French, Harman, & Dermen, 1976). If individual differences were a determining factor regarding the occurrence of fixation, we might expect that participants with better visuospatial working memory skills (i.e., better scores on the Paper Folding Test) and better design elaboration skills (i.e., better scores on the Elaboration Test) would show significantly less fixation on the experimental task.

Overall, our findings imply that fixation is an instance of negative transfer from examples that may significantly affect problem-solving processes in naive participants. This conclusion broadens the potential negative implications of fixation. It is important to note that our findings do indicate that fixation can be eliminated with the appropriate defixation instructions. A further exploration of the phenomenon of fixation is of great significance not only for cognitive psychology but also for various domains related to technological and scientific education (e.g., Doornekamp, 2001; Heiner, 2002; Stamovlasis, Kousathana, & Angelopoulos, 2002; Won, 2001). In those fields (e.g., physics, chemistry, engineering), learning often occurs through the use of examples in pictorial format. If fixation were identified as a relatively persistent phenomenon in a broad range of educational settings, it would be of great importance to understand its origins and to develop instructional techniques to eliminate its negative effects.

In conclusion, this study is one of the few attempts to investigate experimentally and provide detailed analyses of the conditions under which negative transfer occurs in the presence of examples in pictorial format. Consistent with findings from the design literature on experts, our results support the argument that fixation due to pictorial examples is also observed in naive individuals. Thus, fixation is a general phenomenon that affects individuals irrespective of expertise. Such fixation, however, can be diminished with the use of effective instructions. Further cross-disciplinary research on the exact conditions under which fixation occurs may reveal more details on the phenomenon as well as specify the effectiveness of different instruction strategies in moderating its effects. Whether fixation occurs in tasks of a very different nature (e.g., creative writing tasks) is an empirical question worthy of further experimental investigation.

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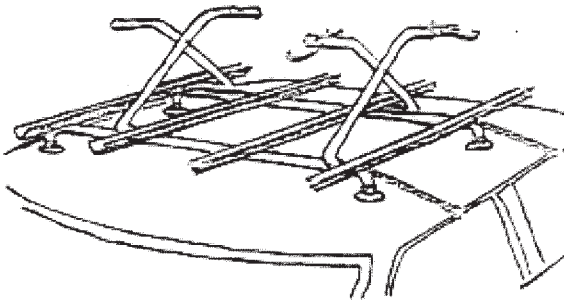
## Appendix

### The Bike Rack and Coffee Cup Problems

#### The Bike Rack Problem (Adapted From Jansson & Smith, 1991)

Suppose you are asked to construct a new bike rack for cars. You should construct as many designs as possible, write comments with each design, and number each individual design. There are no constraints in the materials you may want to use. The problems to be addressed are:

1. Easy mounting of the bicycle
2. Easy mounting of the rack
3. Cannot harm bike or car
4. Must be versatile for all bikes and cars



This is an example of a present day bike rack (see Figure A1). It is a top-mount design having suction cups holding it to the car roof and railings for the bicycle tires. The bicycle is set in the rails and the vinyl coated hook is attached to the seat tube of the bike, and then the hook is tightened down by hand with a wing nut. The problem in this case is the difficulty of mounting the middle bikes on the rack.

In your designs TRY TO AVOID:

1. Using suction cups
2. Generating a top-mount design
3. Using tire railings

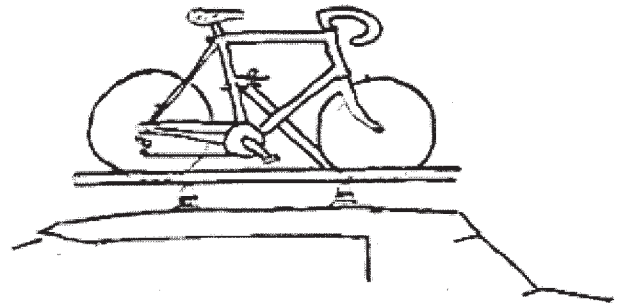


Figure A1. Example design for the bike rack problem. Reprinted from *Design Studies*, 12, D. G. Jansson and S. M. Smith, “Design Fixation,” p. 5, Copyright 1991, with permission from Elsevier.

#### The Disposable Spill-Proof Coffee Cup Problem (Adapted From Jansson & Smith, 1991)

Suppose you are asked to construct an inexpensive, disposable, spill-proof coffee cup. You should construct as many designs as possible, write comments with each design, and number each individual design. There are no constraints in the materials you may want to use. The problems to be addressed are:

1. Leaking of the cup if it tips over
2. Leaking of the cup when squeezed
3. Hot liquid burning the user’s mouth

This is an example of a present day disposable, spill-proof coffee cup (see Figure A2). It is a Styrofoam cup, with a mouthpiece and a straw. The problems in this case are that the straw will leak if the cup tips over and if it is rotated 90° from the angle shown in the diagram; the cup will also leak if it is squeezed, another negative characteristic; finally, the hot liquid emerging uncooled from the straw shown in the example would burn one’s mouth.

In your designs TRY TO AVOID:

1. Using straws
2. Using mouthpieces
3. Using an overflow device

(Appendix continues)

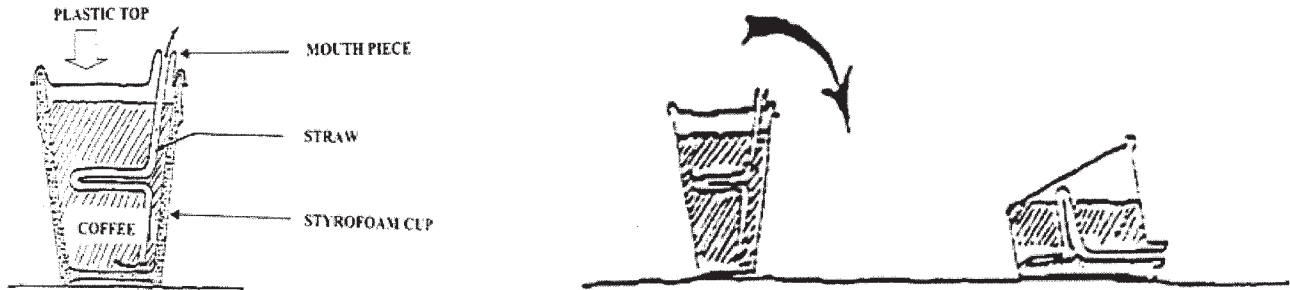


Figure A2. Example design for the coffee cup problem. Reprinted from *Design Studies*, 12, D. G. Jansson and S. M. Smith, "Design Fixation," p. 8, Copyright 1991, with permission from Elsevier.

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### Correction to Rothermund et al. (2005)

In the article "Retrieval of Incidental Stimulus–Response Associations as a Source of Negative Priming," by Klaus Rothermund, Dirk Wentura, and Jane De Houwer (*Journal of Experimental Psychology: Learning, Memory, and Cognition*, 2005, Vol. 31, No. 3, pp. 482–495), Table 1 (p. 484) was incorrectly typeset. The correct layout appears below.

Table 1  
*Sample Stimuli of Prime–Probe Sequences in Experiment 1*

Priming condition	Response relation between prime and probe			
	Same response		Different response	
	Prime	Probe	Prime	Probe
Same word	<b>SHORT</b>	SHORT	<i>SHORT</i>	SHORT
	<i>TABLE</i>	TABLE	<b>TABLE</b>	TABLE
Same category–different word	<b>DRY</b>	SHORT	<i>DRY</i>	SHORT
	<i>WATER</i>	TABLE	<b>WATER</b>	TABLE
Different category	<b>TABLE</b>	SHORT	<i>TABLE</i>	SHORT
	<i>SHORT</i>	TABLE	<b>SHORT</b>	TABLE

*Note.* Prime words in **boldface** were shown to participants in green; prime words in *italics* were shown to participants in yellow. Examples refer to a response assignment in which *green* and *adjective* were assigned the same response key.