# The impacts of examples on creative design : explaining fixation and stimulation effects

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# THE IMPACT OF EXAMPLES ON CREATIVE DESIGN:EXPLAINING FIXATION AND STIMULATION EFFECTS

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## ABSTRACT

Converging evidences have indicated that the ability to generate creative ideas could be limited by recently activated knowledge such as examples of solutions. However, neuroimaging studies have recently demonstrated that exposure to examples did not systematically lead to fixation and could on the contrary have a stimulation effect on creativity.Our hypothesis is that there are two types of examples that C-K theory helps to characterize: (1) restrictive examples that do not change the definition or the attributes of the object, and (2) expansive examples that modify its identity by adding unexpected attributes. In two studies, we explored the impact of restrictive and expansive examples ona creative task. We then hypothesized that the introduction of an example during the task would provoke participants to propose solutions of a higher originality when the provided example was expansive. In contrast, when the provided example was restrictive, we hypothesized that the originality of the solutions would be reduced. Results confirmed that solutions proposed by the group exposed to restrictive example are less original than those given by groups exposed to expansive examples.

*Keywords: Concept-Knowledge Design Theory, fixation effects, example in creativity*

## 1 INTRODUCTION

Today there are large expectations regarding innovation and creativity, and some sectors seem to be less innovative than others. Trendsin cognitive psychology have clarified some obstacles that most people are likely to face in creative situations. More specifically, numerous reports have indicated that recently activated knowledge canconstrain the ability to generate creative ideas [1]. For example, creative problem solving can be inefficient when the solution requires subjects to generate an atypical object function and when the object's typical function has been primed [2]. In the psychology literature this effect is labeled as thefunctional fixedness or fixation. In the same vein, converging evidence reports a fixation bias when subjects are asked to generate new ideas after being exposed to solution examples.

Nevertheless, in the specific field of neuroimaging,recentstudies have made significant contributions to our understanding of the neuro-cognitive influence of ideas produced by other people by demonstrating anopposing trend [3]. Indeed, in contrast with the fixation phenomena, this work highlightsthat creative cognition can be improved effectively by means of the ideas of others. Although the discrepancies in the results of these studies underscore the need for further and focused research inthis field, little is known about the potential impact of the nature of examples in the realmcreativity. This lack of knowledge is regrettable if one considers that examining the precise influence of different types of examples on idea generation may provide experimental arguments enabling to reconcile studies showing either provocative or constraining effects of examples.

In the field of design science, the development of C-K theory modeling creative reasoning[4],[5]offers a new and rich interpretation of both the fixation and the stimulation effects.Our hypothesis is therefore that there are two types of examples that C-K theory helps to characterize: (1) restrictive examples that do not change the definition or the attributes of the object, and (2) expansive examples that modify the identity of the initial task by adding unexpected attributes. We build therefore a

framework that allows us to characterize the nature of examples that provoke either fixation or stimulation effects.
The purpose of this paper is to examine the impact on creativity in relation to the nature ofthe examples. We do this via a creative task where the aim is to design a way to drop a hen's egg from a height of 10m so that it does not break. We choose this familiar task because it requires minimal engineering expertise and allows many possible solutions.We then use C-K theory to chartresponses that do not include only fixation effects and to characterize the nature of the type of responses that can be possible solutions. In this way, we will test how restrictive examples andexpansive examples impact the originality of the solutionsto the design task.

## 2 LITERATURE REVIEW

### 2.1 Fixation and stimulation effect

Over the last six decades, numerous reports in the psychological literature have indicated that the ability to generate creative ideas could be limited by recently activated knowledge. One of the most well known examples of this failure in the domain of creative problem solving is the phenomenon of functional fixedness. Here, people fail to see new ways of using objects that could lead to an original solution to a problem, because they remain bound topreviously activated prescription of theobject. For example, in the ‘candle problem’[6], [7], subjects are provided with a candle, a book of matches and a box of tacks, and asked to fix the candle to a vertical screen in such a way that it will burn without dripping wax on the table below. The solution tothis problem requiressubjectsto use the tack box in an unfamiliar way:as a platform. Adults failed to spontaneously find this solution when the box was presented full of tacks. In other words, priming the box’s typical function blocked the subjects’ ability to use the box in an atypical manner. Traditional interpretations of functional fixedness suggest that accumulated knowledge about thetypical properties of the object isautomatically activated and blocks alternative uses of the object.
Another famous example of the fixation effect was reported by Smith, Ward and Schumacher [8], who observed and described the constraining effects of the examples used in generating creative ideas. In the classical task, participants were required to imagine and draw animals that lived on another planet that were very different to those on Earth. Prior to the drawing of the animal, participants areexposed to examples that have fundamental elements in common (such as eyes, antennas,…). Two independent assessorsnoted then whether the subjects’ drawings contained any of these elements. Results showed that participants tended to incorporate these elements in their owndrawing, despite an explicit warning to avoid replicatingfeatures given inthe examples. (see also [9]).
Interestingly, exposure to examples did not systematically lead to fixation. Indeed, in the domain of brainstorming, exposure to ideas from others can stimulate associations that lead to the generation of additional ideas. In one experiment, Dugosh and Paulus [10] reported that participants generated more unique solutions when a list of eight ideas was given prior to the brainstorming session. The neural basis of this stimulation effect has been recently investigated in a functional Magnetic ResonanceImaging(fMRI) study. Using a creative idea generation task where participants wererequested to generate alternative uses of conventional everyday object such as an umbrella, Fink et al. [3]reported that creative performance increases after the exposure toexamples of solutions. At a neurophysiological level, cognitive stimulation with ideas from others is associated with activation increase in a neural network involved in memory retrievaland attentional processes. Altogether these results indicate an interaction between an external idea and participants’ memory and therefore suggest that exposure to examples of a solution could modulate the bottom-up attention and retrieval of novel associations, allowing participants to produce more original ideas. Nevertheless, these studies provideno cluestoaid usin understanding why examples lead to fixation effectsin some situationswhereasin otherstheystimulate creativity.

### 2.2 Characterizing restrictive and expansive examples

According to us, theoretical work in design science provides insights on describing different features of solutions to a design task. C-K design theory or concept-knowledge theory models the creative process as the interrelated expansion of two spaces[4],[5]. One space (the Concept space) is tree structured and describes the progressive and stepwise generation of “temptative alternatives”, which are usually indecidable propositions before a“conjunction” can beinterpreted as “a solution”; the other space (the Knowledge space) is formed by the network of memorized and activated knowledge that is used for the generative process of the C-Space. One of the recognizedbreakthroughs provided by C-K theory is that it revealsthat to obtain a creative solution both processes have to reinforce each other: thinking of an alternative changes the activated sets of knowledge and also vice versa.

C-K theory sets the framework of a design process based on refining and expanding the initial concept by adding attributes stemmingfrom the knowledge space. The initial concept-set is thus partitioned step-by-step in several increasingly more refined sub-concepts. There are however two kinds of partitions [4]. The restrictive partition is a partition where we restrict the space of possibilities without changing the definition or the attributes of the object or process to design. However, sticking to restrictive partitions does not allow the redefinition of objects; an expansive partition is a partition that modifies the identity of the initial design object by adding unexpected attributes to that of the initial concept. It is precisely because of those expansions that the true innovation, including surprises, is possible.

In this context, C-K theory explainsthe fixation effect as arising from both a limitation of C and K expansions. Interestingly, the theory predicts that people tend to generate ideas that are most accessible in memory. This activation of common knowledge could lead to fixation effects. Consequently, we hypothesized that external cues reinforcing the activation of these common knowledge should increase the fixation effect. On the contrary, example of solutions that activate knowledge that are less spontaneouslyaccessible should reduce the fixation effect and therefore stimulate creativity.

## 3 GENERAL PROCEDURE

Our investigation is divided in two phases: (1) identifying restrictive and expansive examples using C-K reasoning, (2) examining the potential impacts on originality of both types of examples based on the results of the first phase.

Therefore, we first used C-K theory to explore possible paths of innovation, capturing the possible generation of new knowledge and objects on the matter of dropping an egg without breaking it. In a first study we aimed to determine both fixation path based on spontaneous knowledge and expansive path activating knowledge that is less accessible. In a pre-test session, a group of participants was asked to give solutions to the egg task. We then used this natural distribution of solutions in order to control that expansive solutions require an expansion of knowledge (ie the activation of a set of knowledge that is not spontaneously activated when designing a solution to the egg task).

Then, using results of this first study, we identified restrictive and expansive examples. We then examined their specific impact on originality in a second study, where three groups of participants were asked to solve the egg task while given either of those examples. A fourth group was then given both restrictive and expansive examples.

## 4 STUDY 1: METHOD TO IDENTIFY RESTRICTIVE AND EXPANSIVE EXAMPLES

### 3.1 The use of C-K theory

To use C-K theory in our case, we first gathered the knowledge and expertise and the solutions usually proposed on the topic (such as shells, mattresses, parachutes). Our hypothesis was that this knowledge basis is the one that is classically activated while solving this task (see table 1). We then expanded in the C-space by making explicit the hidden partition that had been chosen to achieve the design of devices that change either the reception or the fall: those solutions design the drop of an egg from a 10-meter height without breaking it, using a device that is inert (eg not living). The expansions (a) without using a device and (b) using a living device pushed us to expand in the K-space, to look for new knowledge (on the egg properties, on living devices, etc), that then allowed us to think of new expansions in the C-space (using the natural properties of the egg or modifying them).

*Table 1: Sequences to build the C-K diagram*

| Phase | In the K-space | In the C-space |
|---|---|---|
| **Phase 1 Gathering of spontaneous knowledge** | Model of dropping an egg from a 10meters height. Knowledge on gravity, fall, reception, forces. Benchmark of existing solutions: shells, mattress, parachutes. Some knowledge about the fragility of the egg | Choice between a focus on the reception (damping the shock or protecting the egg) or a focus on the fall (slowing it) |
| **Phase 2 Expansion in C-space** | | Partition on device / with no device, and inert device / living device. |
| **Phase 3 Expansion in K-space** | Knowledge on the properties of the egg, properties of the drop, of the environment Knowledge on living devices that break falls, or that reception well. | |
| **Phase 4 Expansion in C-space** | | Using the natural properties of the egg, modifying them |
| **And going** | … | … |

The use of C-K theory allowed us to map the possible solutions axis, as it is shown on the Figure 1. Thus, our hypothesis is that the use of C-K theory helped us to think of possible paths of solution that do not come spontaneously to mind (training an eagle to catch the egg, using the natural robustness of the longitudinal axis of an egg, freezing the egg, etc). We therefore examined in this first study whether the paths of solutions generated by the C-K reasoning are more than the fixation effects paths.

### 3.2 Participants

Twenty-eight undergraduate students in psychology from Paris Descartes University were recruited for this study. Subjects were between 17 and 22years old (mean age: 18,8years). Participants didn't have previous experience with design project.

### 3.3 Procedure

Each participant was given 10 minutes to generate as many original solutions to the following problem:

> "You are a designer and you are asked to propose as many original solutions as possible to the following problem: Ensure that a hen's egg dropped from a height of 10m does not break."

### 3.4 Results

As illustrated in Figure 1, analysis of responses given by the participants revealed a strong fixation effect. Indeed, 81 % of the responses consist in using an inert device in order to damp the shock (33 %), protect the egg (26 %), or slow the fall (22 %)($\chi^2$ significant at $p <.0005$). One good example of solutions in this fixation path based on common knowledge is to slow the fall with a parachute. On the contrary, solutions belonging to expansive paths were less often proposed by the participants ($\chi^2$ significant at $p <.0005$). Interestingly, less than 10 % of the responses consist in using a living device (4%) or in modifying the natural properties of the egg (3%). Examples of solutions belonging to these expansive paths are to train an eagle to catch the egg during the fall or to freeze the egg before dropping it.

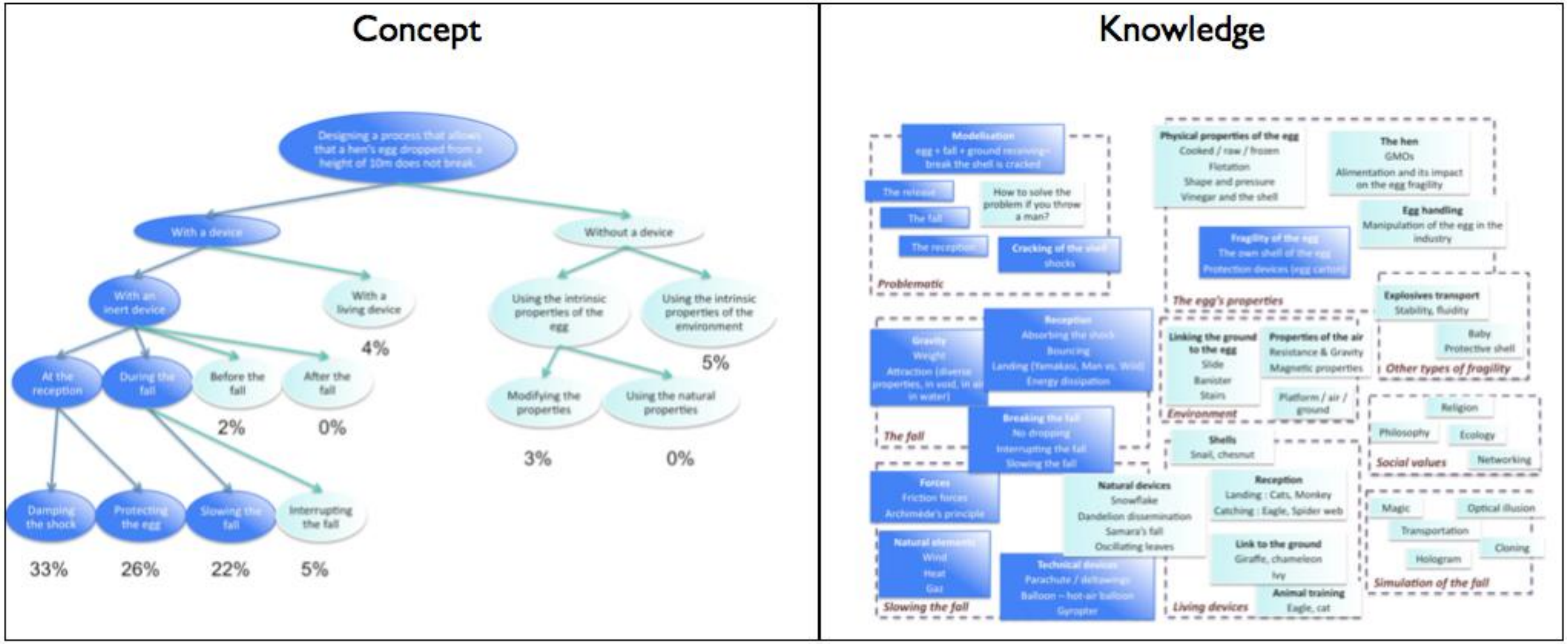


*Figure 1 : C-K diagram for Study 1*

The key aim is now to determine whether examples belonging to the fixation path (restrictive examples) and examples belonging to expansive paths (expansive example) have an opposite effect on participants' ability to generate creative ideas.

## 5 STUDY 2 : IMPACTS OF EXAMPLES ON ORIGINALITY

In the present study, we explored the impact of restrictive and expansive examples on creativity in the egg task. Based on C-K theory, we hypothesized that the introduction of example during the egg task would provoke participants to propose more original solutions when the provided example was expansive (i.e. belonging to the expansive paths evidenced in the first study). In contrast, when the example provided was restrictive (i.e. belonging to the fixation paths evidenced in the first study),we hypothesized that the originality of the given solutions would be reduced. We have then conducted two analyses, one on the mean number of solutions and one on an objective originality score of those solutions.

### 4.1 Participants

One hundred and thirty two undergraduate students from Paris Descartes University were recruited for this study. Subjects were between 17 and 28years old (mean age: 19,1years). Participants were tested at the same time in a large room. All participants were naïve regarding the experimental aims and didn't have previous experience with design project.

### 4.2 Procedure

Each participant was randomly assigned to one of the four experimental conditions and was given 10 minutes to generate as many original solutions to one of the following problem.

- Control group (n=28): Without example
  "You are a designer and you are asked to propose as many original solutions as possible to the following problem: Ensure that a hen's egg dropped from a height of 10m does not break."

- Group A (n=25): Restrictive example
  "You are a designer and you are asked to propose as many original solutions as possible to the following problem: Ensure that a hen's egg dropped from a height of 10m does not break. The most often proposed solution is **to slow the fall with a parachute**"

- Group B (n= 27): Expansive example 1
  "You are a designer and you are asked to propose as many original solutions as possible to the following problem: Ensure that a hen's egg dropped from a height of 10m does not break. One possible solution is **to train an eagle to catch the egg during the fall**."

- Group C (n= 26): Expansive example 2
  "You are a designer and you are asked to propose as many original solutions as possible to the following problem: Ensure that a hen's egg dropped from a height of 10m does not break. One possible solution is **to freeze the egg before dropping it**."

- Group D (n= 26): Restrictive example and Expansive example 1
  "You are a designer and you are asked to propose as many original solutions as possible to the following problem: Ensure that a hen's egg dropped from a height of 10m does not break. Your company specializes in **parachute slowing the fall of the eggs**. A competitor recently proposed as a solution the **training of an eagle so that the eagle catches the egg in the air**."

### 4.3 Results

In order to examine whether the number of solutions proposed varied according to the experimental conditions, we conducted one factor analysis of variance (ANOVA) with the experimental groups (A, B, C, and D) as a between-subjects factor. This analysis revealedthat main effect of experimental groups is close to reach significance ($F(4,129) = 2.09$ $p = .08$), indicating that our experimental conditions affect the number of solutions given by the participants. Interestingly, the two groups exposed to restrictive examples proposedfewer solutions than the others groups (see Figure 2). It should be noted that we measured the simple count of solutions generated and not a count of solution types.

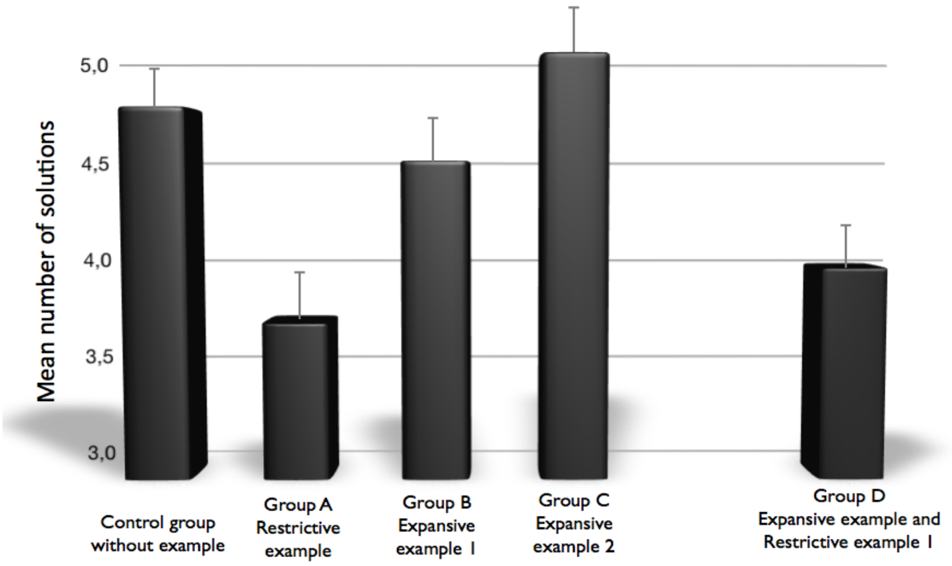


*Figure 2 :Mean number of solutions according to the experimental groups*

As usual in divergent thinking literature, we computed an objective measurement of originality of solutions by taking the frequency of responses given across all the subjects in each group. In this score, originality of a solution is defined as the statistical infrequency of that particular solution. For example, if less than 5 % respondents report a response, that response is considered to be of high originality. On the contrary if more than 95 % respondents report a response, that response is considered to be of low originality. Thus, we obtained a mean originality score between 0 and 1 for each participant where 0 represents the lower level of originality and 1 the higher one (see Figure 3).
These scores were subjected to one factor ANOVA with the experimental groups (A, B, C, and D) as a between-subjects factor. This analysis showed a main effect of experimental groups ($F(4,129) = 11.219$, $p < .0005$), indicating that the presence of examples have a significant impact on the originality of solutions.

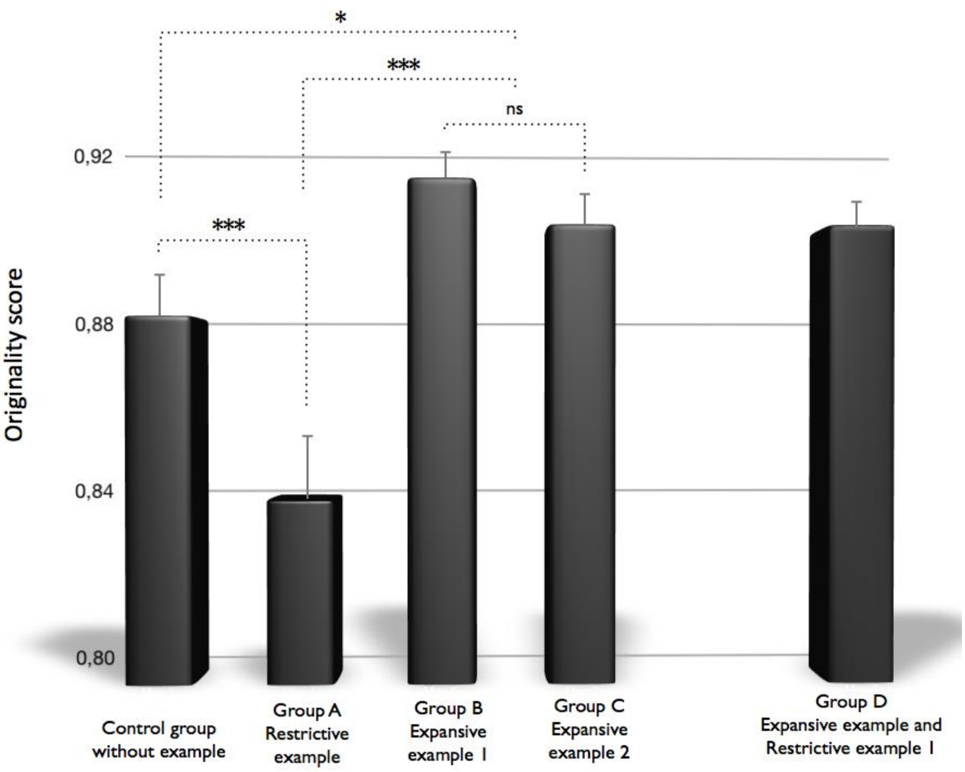


*Figure 3 :Originality score according to the experimental groups*

Post-hoc comparisons revealed that solutions proposed by group A are less original than those given by the control group ($p < .005$), or group B ($p <.005$) and the group C ($p <.005$). This suggested that the exposure to restrictive example reduces the originality of the solutions. On the contrary, our data showed that the two groups exposed to expansive examples proposed more original solutions than the control group without example ($p = .07$). Interestingly, participants who received both a restrictive and an expansive examples are more original than those in group A ($p <.0005$) with restrictive example solely. Note that there was no significant difference between group D and the two other groups with expansive examples (all p's >.05).
Beside our data also revealed that globally the first solution given by the participants is less original than the last one ($F(1,129) = 28.59$, $p < .0005$) even if there is no significant interaction between experimental groups and the first/last factor ($F < 1$).

## 6 DISCUSSION AND CONCLUSION

In the two studies, we explored the impact of restrictive (i.e. belonging to the fixation path) and expansive (i.e. belonging to the expansive paths) examples on a creative task that is to design a way to drop a hen's egg from a height of 10 m so that it does not break. Four major findings emerged from this investigation: (i) participants' ability to generate a creative idea is blocked by solutions that come spontaneously to mind, leading to fixation effect (ii) the introduction of expansive example during the egg taskled participants to propose more original solutions (iii) in contrast, when the example provided was restrictive, both the number and the originality of solutions were reduced; (iv) interestingly when both a restrictive and an expansive examples were presented in the design brief, participants gave fewer solutions without affecting the originality.
As predicted by C-K theory, our first study revealed strong fixation effects indicating that participants gave solutions based on common knowledge spontaneously activated. This result is in keeping with studies in the domain of reasoning that demonstrated the involvement of an intuitive/automatic system in problem solving [12]. In other words, when people have to solve a problem in a creative way they are constrained by automatic activation of common knowledge leading them to give usual solutions.

Interestingly enough, when the activation of this common knowledge is reinforced by the presentation of possible solutions belonging to the fixation path, participants proposed fewer solutions that were also less original. This finding is in line with several previous works and confirms that recently activated knowledge can strongly constrain the ability to generate creative solution [1], [8].
One major result of the present investigation is that expansive example produces the opposite effect on originality. Indeed, providing example belonging to an expansive path in the C-space increases creative performance. Although this result confirms that a stimulation effect of example is possible [10], [3], see also [13],[14] it can appear contradictory with regardsto the vast number of studies mentioned previously reporting that examples block creativity. However thanks to C-K theory we can suggest explanation of this apparent discrepancy. The exposure to an expansive example unveils a possible expansion in the C-space to the participants, which is not the case for a restrictive example. Thus, expansive example provides with a set of alternatives in the C-space: using a living device, modifying the properties of the egg. This expansion could be however limited to the C-space in the sense that participants did not have access to ways to expand their knowledge (for instance via the internet). In addition our results suggest that participants did not transfer the fixation from the common path to the expansive examples given in the present experiment.

A limitation of our study is thatwe computed an objective measurement of originality of solutions without taking into account the appropriateness of the solutions given by the participants. Yet, a creative idea is original, but an original idea is not always creative. Therefore, it would be interesting in future works to use an external rating procedure similar to the Consensual Assessment Technique (CAT) proposed by Amabile. Although the marked interest for the study of the impact of external cues on creativity, there are many loose ends in the field and little is known about the neuro-cognitive processes allowing (1) to control routine strategies and (2) to generate new creative ones. Using both new modeling of creative reasoning and recent advance in neuroimaging techniques it would be possible in future work to directly observe the neural activity associated with (i) thefixation effect (ii) the neuro-cognitive impact of both restrictive and expansive examples.

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