CREATIVITY RESEARCH JOURNAL
https://doi.org/10.1080/10400419.2024.2424620

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Detecting Fixation Bias in Creative Idea Generation: Evidence from Design Novices and Experts

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ABSTRACT
Recent theories of creative thinking propose that the generation of creative ideas by design novices and experts is restricted by the emergence of intuitive cognitive biases. To overcome these biases and explore expansive solutions, biased ideas must be discriminated from those with creative potential. Although studies in the field of reasoning have shown that biased participants tend to detect an incongruency between their provided solutions and the expected solution, the use of conflict detection in creativity has never been studied. Two experiments were conducted to determine the extent to which conflict detection occurs during creative idea generation and whether this mechanism is available for design novices (Experiment 1) and/or experts (Experiment 2). The results indicated that both groups of participants detected their fixation bias and managed to overcome it by switching from intuitive to deliberate thinking. In addition, we discussed implications for popular current (dual process) models.

ARTICLE HISTORY
Received January 12, 2024

Introduction

Alexander Fleming revolutionized modern medicine by examining a mold that had developed on an accidentally contaminated Staphylococcus culture plate and observing that the mold prevented the growth of staphylococci. Fifteen years after this discovery, he explained that "it is also probable that some bacteriologists have noticed similar changes to those noted above, but that [. . .] the cultures have simply been discarded" (Fleming, 1944). Fleming's case illustrates that a breakthrough innovation might require not only the generation of an idea or a solution with high creative potential (e.g., antibiotics obtained from Penicillium molds) but also the ability to detect that a usual answer needs to be excluded (e.g., avoid discarding the cultures). This ability to detect both creative and uncreative solutions to a problem is echoed in current debates on the role of conflict detection in the domains of reasoning and decision-making (Bago & De Neys, 2019a; De Neys, 2014; De Neys et al., 2008; Kahneman, 2003; Kahneman & Frederick, 2002).

Decades of research in the reasoning and decision-making domains have suggested that individuals are often biased by intuitive thinking and easily violate basic logical principles (De Neys & Pennycook, 2019; Houdé & Borst, 2014; Kahneman, 2003). However, recent empirical studies have shown that people can detect that their intuitive answers are not fully warranted, causing conflict with logical considerations (De Neys, 2014; Frey et al., 2018). This ability to discriminate biased (e.g., wrong) from unbiased (e.g., good) answers is termed "conflict detection" (De Neys, 2014). In parallel, the creative problem-solving literature has demonstrated that creativity can also be blocked or impeded by intuitive thinking, leading to a cognitive bias called the fixation effect (Camarda, Borst, et al., 2018; Cassotti, Agogué, et al., 2016; Cassotti, Camarda, et al., 2016; Lloyd-Cox et al., 2020). Although considerable efforts have been devoted to identifying the role of conflict detection in the domains of reasoning and decision-making (e.g., De Neys & Pennycook, 2019; Houdé & Borst, 2014; Kahneman, 2003), to date, no studies have examined whether individuals are able to detect conflict in the generation of creative ideas. In other words, there is no evidence that participants are able to discriminate whether they generated biased (according to their fixation effect) or unbiased ideas.

Therefore, the present study aimed to investigate the extent to which conflict detection, as observed in reasoning studies, also occurs in the generation of creative

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Supplemental data for this article can be accessed online at https://osf.io/u4jmv/

ideas by design novices (Experiment 1) and design experts (Experiment 2). Moreover, the relationship between the cognitive models used in reasoning studies and those used in creative cognition studies was investigated.

Fixation effect in creative idea generation

Like studies in the fields of reasoning and decision-making, which have revealed cognitive biases in various domains, including reasoning (De Neys & Van Gelder, 2009; Frey et al., 2018), probability judgment (Mevel et al., 2019), and risky decision-making (Reyna et al., 2014), studies in the field of creativity have reported that individuals might fail to produce original solutions to a problem because of cognitive biases (Cassotti, Agogué, et al., 2016; Duncker & Lees, 1945; Storm & Angello, 2010; Ward, 1994a, 2007).

One of the main findings in recent studies is that the fixation effect is a major obstacle in creative idea generation and the innovation process. The fixation effect arises from the mobilization of knowledge and typically used solutions acquired in contexts that are similar to those faced by an individual. This information is used as a mental dataset that is useful in many situations, but it can hinder the generation of alternative solutions during creative problem solving (Ward, 1994b, 2007). For example, when participants are asked to "ensure that an egg dropped from a height of 10 meters does not break," they fixate on a limited number of uncreative categories of solutions and fail to explore more original solutions (Camarda et al., 2017; Cassotti, Agogué, et al., 2016; Cassotti, Camarda, et al., 2016). Fixation effects have been demonstrated in children (Agogué et al., 2014; Cassotti, Agogué, et al., 2016), adolescents (Agogué et al., 2014; Camarda et al., 2021), young adults (Cassotti, Camarda, et al., 2016; Purcell & Gero, 1996), and experts in industrial design or engineering (Agogué et al., 2015; Camarda et al., 2017; Crilly, 2015).

According to the triadic dual model of creativity, which is based on general dual-process models (Cassotti, Agogué, et al., 2016), the fixation effect observed in creative problem solving and idea generation arises from intuitive System 1, which is assumed to operate quickly and effortlessly. System 1 corresponds to the "path of least resistance" (Ward, 1994b). These dual-process models rely on the theory that creative idea generation uses cognitive control (the so-called System 3) to inhibit the first intuitive response to consider alternative solutions through System 2, which is presumed to be slower and require more effort. Thus, providing original solutions to problems such as the egg task requires cognitive control of the intuitive (uncreative) solutions (Camarda, Borst, et al., 2018; Camarda, Salvia, et al., 2018; Cassotti, Agogué, et al., 2016).

In support of this model, many studies have shown that cognitive control is a key process in creative idea generation. A series of behavioral studies have reported positive correlations between inhibitory control measures such as the Stroop task or the Hayling test and creative performance in adults (Benedek, Jauk, Sommer, et al., 2014; Camarda, Borst, et al., 2018; Zabelina & Robinson, 2010; Zabelina et al., 2019). In addition, Camarda, Borst, et al. (2018) demonstrated that impeding cognitive control by adding a cognitive load using a dual-task paradigm reduced not only fluency (i.e., the number of ideas generated) but also the originality of the solutions provided in a creative task. Moreover, neuroimaging investigations have shown that creative ideation is associated with the activation of specific prefrontal brain regions, which are known to be involved in cognitive control during creative ideation (Beaty et al., 2015, 2016, 2018; Benedek et al., 2011; Benedek, Jauk, Fink, et al., 2014; Camarda, Salvia, et al., 2018; De Souza et al., 2014).

Conflict detection, a key mechanism in dual-process models

Although the previous findings show that inhibitory control is involved in resisting fixation effects in creative ideation (Camarda, Borst, et al., 2018), these studies provide no insight into the development of conflict detection in creative problem solving. While conflict detection is widely recognized as a key mechanism in the dual-process theories in reasoning studies (De Neys, 2023; Pennycook et al., 2015), creativity studies have not yet considered its effect or adaptation. However, using a variety of methods, recent experimental investigations on conflict detection in reasoning and decision-making have clearly indicated that despite their biased responses, individuals are often able to detect that their intuitive answers conflict with normative principles and are not fully accurate (De Neys, 2014; De Neys & Glumicic, 2008; Raoelison, Boissin, et al., 2021). For example, consider the famous "bat and ball problem," one of three items included in the Cognitive Reflection Test (CRT; Bago et al., 2019; Bago & De Neys, 2019a; Frederick, 2005; Raoelison & Neys, 2019): "*A bat and a ball together cost $1.10. The bat costs $1 more than the ball. How much does the ball* cost?" Although this problem appears easy, for most adolescents and adults, an intuitive wrong response spontaneously comes to mind: *10 cents*. Participants incorrectly subtract *$1.00* from *$1.10* and thus ignore a fundamental and explicitly mentioned part of the problem, which is that "*The bat costs $1 MORE than the ball.*" Thus, the correct response is "*5 cents*;" if the ball costs 5 cents and the bat costs $1 more (*$1.05*), the total cost of the bat and ball corresponds to the information given in the problem instruction (*$0.05 + $1.05 = $1.10*). Even if a vast majority of individuals give an intuitive but incorrect response to these problems, empirical evidence suggests that they may detect that their answer is biased (Bago & De Neys, 2019a; Bago et al., 2019; Raoelison & Neys, 2019).

These conflict detection studies typically compare participants' confidence in their biased responses in a conflict condition (CC; i.e., the intuitive incorrect response conflicts with the logical response) and a no-conflict control condition (i.e., the intuitive response is congruent with the logical response). In the context of the bat and ball problem, a no-conflict control problem requires that the tendency to subtract one of the elements from the total cost provided in the instruction achieves the correct answer, as follows: "*A magazine and a banana together cost $2.90. The magazine costs $2. How much does the banana cost?*" The results established that adults display lower confidence in their biased responses to the conflict problem than in their correct response to the control problem. These findings suggest that even if their responses are biased, individuals can detect that their reasoning is not fully accurate, as indicated by a lower confidence score. In addition, recent investigations have expanded these results by confirming that conflict detection is a core process involved in many areas of reasoning and decision-making (De Neys, 2014), including arithmetic (De Neys et al., 2014), grammatical reasoning (Lanoë et al., 2017), deductive reasoning (Frey et al., 2018), probability judgment (Mevel et al., 2019) and even moral judgment (Bago & De Neys, 2019b; Bialek & De Neys, 2017).

The assumption that individuals are aware of the questionable nature of their intuitive answer has been validated with the use of a two-response paradigm in reasoning tasks (Bago & De Neys, 2019a; Bago et al., 2019; Raoelison & Neys, 2019). Typically, the participants are asked to provide an initial response under time pressure to constrain the activation of System 1 (automatic and fast) and force the emergence of intuitive responses. Then, participants are given additional time to provide a final response after deliberation, allowing them to access System 2 (deliberate and slower). The findings clearly demonstrated that most participants provided biased and incorrect responses under time pressure in the first phase of conflict problems. However, some reasoners were able to correctly solve the problem even when time pressure reduced access to the resources needed for deliberation (Bago & De Neys, 2019a; Raoelison, Boissin, et al., 2021). Thus, using a two-response paradigm, these studies corroborate that reasoners can intuitively detect that the biased response is not fully accurate, but some individuals may demonstrate intuitive logic (i.e., they intuitively reach the correct and logical solution under the time constraint).

Strengthening the link between creativity and reasoning models

Thus, drawing inspiration from the reasoning literature, which has highlighted and modeled different forms of reasoning bias, the triadic model of creativity (Cassotti, Agogué, et al., 2016) has enabled the understanding and modeling of the cognitive processes that induce fixation effects during creative idea generation. However, while the dual-process models in reasoning have evolved to include the fundamental involvement of the conflict detection mechanism (De Neys, 2014; De Neys & Glumicic, 2008; De Neys & Pennycook, 2019), the triadic model of creativity does not yet consider this important mechanism.

Previous studies have investigated individuals' ability to evaluate creative ideas and demonstrated that this ability can be influenced by factors such as their expertise in a domain (Amabile, 1982) or cultural differences (Niu & Sternberg, 2001). However, the cognitive process of conflict detection differs from the simple ability to evaluate the creativity of an idea since conflict detection aims to discriminate ideas generated using System 1 (heuristic) from those generated using System 2 (deliberative; De Neys & Pennycook, 2019). Thus, conflict detection is not directly associated with the evaluation of the creativity of the idea itself but rather the nature of the Systems that are at the origin of its generation and how relevant (or biased) the answer is to the problem.

In the context of reasoning biases presented as a convergent thinking task, such as the bat and ball problem (Bago et al., 2019), only one answer is correct, and a biased individual generates an erroneous response. From this perspective, conflict detection combines both the individual's capacity to doubt the correctness of the response and the capacity to detect that this response was generated by System 1.

Investigating conflict detection in the framework of creative idea generation represents an evolution in the understanding and modeling of the cognitive processes of not only creativity but also reasoning. Showing that the conflict detection mechanism exists during a divergent thinking task in which the participant can (and must) generate numerous ideas that do not have truth status suggests that this mechanism is linked not to the truthful status of the response but rather to the effort made to generate it automatically (System 1) or deliberatively (System 2).

Current study

Collectively, these previous studies showed that conflict detection is a core process involved in reasoning and decision-making. However, no study has examined whether conflict detection occurs in creative idea generation when individuals seek to overcome the fixation effect to provide an original solution to a problem. Therefore, in the current study, whether participants who exhibit a fixation effect in creative idea generation can detect that their biased response is not accurate was investigated. In other words, can individuals detect that they are fixated on uncreative responses that are not relevant when they are asked to generate creative ideas to solve a problem?

Studies proposed in the creativity domain have largely demonstrated that even if the nature of the fixation effect can vary across samples according to participants' knowledge, the fixation effect reduces the exploration of expansive solutions, regardless of the participants' age and expertise (Agogué et al., 2015; Camarda et al., 2017; Cassotti, Camarda, et al., 2016; Chrysikou & Weisberg, 2005; Crilly, 2015; Purcell & Gero, 1996). However, studies in the reasoning and decision-making fields suggest that experts in the studied domain could have more logical intuition and could be better at detecting biases. In fact, Kahneman (Kahneman, 2003; Kahneman & Frederick, 2007) has shown that humans can often be illogical, even when they benefit from the best education program (Kahneman & Klein, 2009); Other work has highlighted that experts can be less biased than novices and exhibit intuition that is directly more relevant (Kahneman & Klein, 2009; Klein et al., 2017). Thus, two experiments performed with design novices (Experiment 1) and experts (Experiment 2) were proposed to study the impact of expertise on the ability to detect and overcome the fixation effect when intuitive responses are forced and when the participants are given 5 minutes to generate as many solutions as they can.

Experiment 1

The aim of the first experiment was to examine whether novice adults can detect when they are fixated on uncreative responses that are not relevant when they performed a creative task.

To do so, participants completed a generative problem-solving task in the CC (i.e., in which the participants had to avoid fixation to explore creative solutions) and another in the no-conflict condition (NC; i.e., the participants had to provide common solutions and could thus provide intuitive solutions in agreement with the instructions).

We used an adaptation of the two-response paradigm designed by Bago and De Neys (2017) to assess both initial intuitive responses and responses provided after deliberation. In the initial step, the participants were asked to provide their first response to the problem under time pressure (i.e., less than 10 seconds). After this initial response, the participants were asked to evaluate their confidence in the relevance of their answer according to the goal of the task (i.e., providing a creative solution for the CC or a common solution for the NC) using a 7-point scale. Finally, the same problem was presented again, and the participants were given ten minutes to provide multiple creative solutions in the CC or common (usual) solutions in the NC. Participants were instructed to indicate a proxy of their confidence for each solution provided as they did for the initial response.

H1: On the basis of previous results obtained in studies of creative problem solving, we hypothesized that the first intuitive response should be generated through the fixation solution path in both the CC and NC, even if the participants were instructed to be creative in the CC. According to the triadic model of creativity (Cassotti et al., 2016), participants should be able to detect the fixation effect and engage in cognitive control to block these spontaneous ideas and activate remote associations to generate creative ideas. Thus, the time constraint placed on participants for their first response should not allow them to access System 2 (slower, effortful). In the egg task, participants would first provide solution ideas in the fixation path, such as dampening the shock, protecting the egg or slowing the fall.

H2: According to recent two-response findings in the reasoning field, some participants might provide intuitive creative responses (i.e., belonging to expansion) during the first phase.

H3: Regarding conflict detection, we reasoned that if adult design novices detect that their first intuitive biased response (i.e., fixation effect) is uncreative, then they should exhibit lower confidence in the relevance of their response in the conflict condition than in the NC. Moreover, they should differentiate the creativity level of their response depending on whether the idea belongs to the fixation or expansion solution path in the CC.

Method

Participants

A total of 229 participants (22% male) were recruited for the experiment. The sample was composed of undergraduate students and workers from different fields and companies. The participants were aged 18 to 60 years (mean age = 29.4 years; *SD* = 12.8). The details concerning the maximum education levels of the participants are presented in the supplementary material. All adults provided written consent, and the participants were tested in accordance with national and international norms governing the use of human research.

Procedure

Each participant was asked to complete the experiment online using Qualtrics software. After reporting their demographic information (age, sex, and education level), they were asked to complete two generative problem-solving tasks with two phases: an initial phase of instruction and verification and a second phase of generation.

In the first phase, the participants were told that they would be asked to solve a problem by generating many different solutions. In this initial instruction phase, the nature of the expected responses (i.e., creative or classic) was indicated depending on the experimental condition the participants were experiencing. Before starting to read the problem and completing the task, the participants answered a manipulation check question to confirm that they understood the type of solutions they had to provide (i.e., creative vs. classic). If the participants answered correctly, the creative problem-solving task was presented. If they failed to answer correctly, they were asked to read the instructions again to understand the type of ideas they would have to generate and to correctly answer the manipulation check question.

After being presented with the creative problem-solving task, the participants entered the second phase, in which they were asked to generate solutions according to the adaptation of the two-response paradigm procedure. In this phase, they were informed that they could generate as many solutions as they wanted because there were no right or wrong answers.

Adaptation of the two-response paradigm to divergent problem solving

To investigate whether conflict detection occurs in creative problem-solving situations, an experimental protocol derived from the classical two-response paradigm used in reasoning tasks was performed (Bago & De Neys, 2019a; Bago et al., 2019; Raoelison & Neys, 2019). After being presented with the problem, the participants completed each task according to the following two steps (Figure 1). For the first generation step, the participants were given only 10 seconds to write the very first answer that came to their minds (Step 1). This time pressure was used to maximize the emergence of the participants' very first ideas, which were expected to be influenced by fixation effects (Bago & De Neys, 2019a). A second-generation step without time pressure was subsequently proposed to the participants (Step 2), who were given 5 minutes to provide as many ideas as possible to complete the generative problem-solving

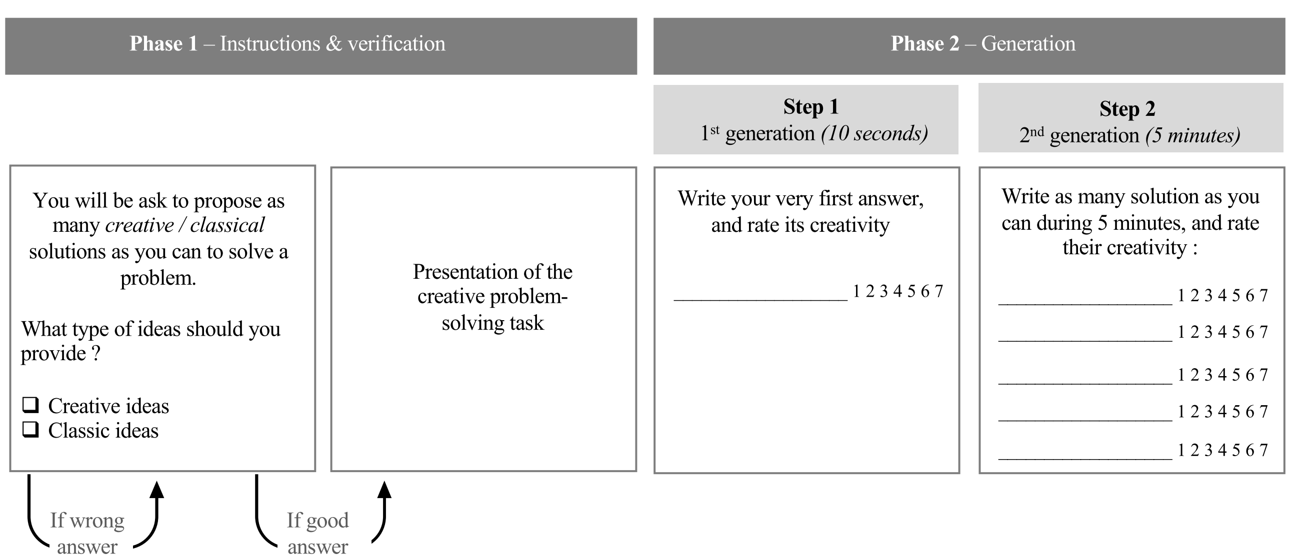

Figure 1. Presentation of the two phases and the two steps of the procedure.

task in a creative or classical way according to the experimental conditions.

Experimental conditions of the divergent problem-solving task

At the beginning of each of the two divergent problem-solving tasks, specific instructions were presented to the participants to operationalize the experimental conditions. As in previous studies that investigated conflict detection in the reasoning domain, one of the tasks was presented in a CC, which involved resisting an intuitive fixation bias, whereas the other was presented in a NC, which did not involve resisting an intuitive fixation bias. In the CC, the participants were asked to provide as many "creative solutions" as possible. Given that creative idea generation is constrained by the fixation effect (generated by System 1; Cassotti et al., 2016), the participants were expected to avoid their first intuitive answer to correctly (i.e., creatively) complete the task. In the NC, the participants were asked to provide as many "typical solutions" as possible. Consequently, the participants could provide ideas within the fixation solution path (i.e., intuitive ideas coming from the use of System 1) since they were not asked to be creative.

To avoid order bias, the order of the conditions (conflict vs. non-conflict) was counterbalanced across participants. Moreover, to avoid the effect of the specificity of the creative task, each participant was presented with only two tasks selected from a pool of four isomorphic tasks.

The four tasks were the egg task, the hole task, the light task and the door task (Figure 2). Each creative problem-solving task was presented to each participant only once. For example, if a participant was first asked to complete the egg task in the CC, then the participant was randomly presented with another task (either the hole task, light task or door task) in the NC.

Measure of the relevancy of participants' answers

During the two generation steps, the participants were asked to generate ideas and judge their level of confidence in the quality of each idea using a 7-point Likert scale (1 = weakly confident, 7 = strongly confident). More precisely, in the CC (i.e., "be creative"), the participants' confidence in the relevancy of their answer was their evaluation of the idea's creativity. In the NC (i.e., "be classic"), the participants' confidence in the relevancy of their answer was their evaluation of the idea's classic aspect, for which the inverse of the creativity scale was calculated. This rating was used to represent the confidence the participants had in the quality of their provided ideas.

Determining fixed and expansive ideas

To determine whether the first intuitive response was biased and part of the fixation path, we applied a well-validated measurement of originality used in previous research on the egg task by determining the distribution of solutions in different categories (Agogué et al., 2014, 2015; Camarda et al., 2018; Cassotti et al., 2016, 2016; Ezzat et al., 2018). A trained rater assigned each solution given by the participant to one of 10 meta-categories, which represent the large categories of solutions that participants can use to complete the task determined through the use of the C-K design method (Hatchuel & Weil, 2009). On the basis of previous studies, solutions falling within three meta-categories that are most commonly used in adult samples (i.e., reducing shock, protecting the egg, and slowing the

Instruction in the CC	Instruction in the NC	Name of the generative problem solving task	Instruction of the generative problem solving task
"Propose as many creative (i.e. original) solutions as you can in order to solve the following problem : …	"Propose as many classical (i.e. non-original, non-creative) solutions as you can in order to solve the following problem : …	**Egg task**	… make sure that an egg dropped from a height of 10 meters doesn't break."
		Door task	… make sure you enter a room to which you don't have a key."
		Light task	… make sure to light up a room without the house's power supply."
		Hole task	… make sure you can communicate with the outside world after falling down a hole."

Figure 2. Presentation of the instructions for the two conditions and the four isomorphic tasks.

fall) represented the fixation effect. The solutions falling within one of the seven other meta-categories represented expansion (i.e., creative ideas) (e.g., using a living object and modifying the natural properties of the egg). The same procedure used in Agogué et al. (2014) for the egg task was used for the three other tasks (the hole task, the light task and the door task), allowing us to categorize each idea as fixation or expansion.[1] Examples of meta-categories and ideas provided in fixation and expansion, for each of the task, are provided in the Figure 3.

These categorizations are available in the supplementary material accessible at https://osf.io/u4jmv/.

Result analysis

Participant performance was analyzed with an analytical method comparable to those used in the two-response paradigm previously presented in the field of reasoning (Bago & De Neys, 2019a). Four analyses were run.

First, the response distribution was analyzed. The nature of the first idea provided by a participant was examined to verify whether this idea was in the fixation solution path (Allen & Thomas, 2011; Camarda, Borst, et al., 2018; Cassotti, Agogué, et al., 2016; Cassotti, Camarda, et al., 2016).

	Withing the fixation path	Withing the expansion
Egg task : Ensure that a chicken's egg dropped from a height of 30ft does not break		
MC	Damping the choc	Change the egg's properties
Idea	Putting a mastress on the floor	Froze the egg
Door task : Make sure you enter a room to which you don't have a key		
MC	Force the classic entrance	Reproduce the presence of the human
Idea	Pick the lock	Enter virtually into the room (e.g., via video conferencing)
Hole task : Make sure to communicate with the outside world after falling into a hole		
MC	Calling with the sound of the voice	Using ntermediaries between the human and the receiving individual
Idea	Shout for someone to hear	Triggering a sound that will be repeated by the birds and amplified
Light task : Make sure to illuminate a room without the power supply of the house		
MC	Use a manufactured object (with an internal electrical source) design to illuminate	Illuminating throught intellectual abilities
Idea	Use a flashlight	An individual shares one of his knowledge and thus creates a mental illumination

Figure 3. Example of meta-categories (MC) and ideas provided both, within the path of fixation and expansion, in each generative problem-solving task.

Second, a response direction of change analysis was performed. The participants' ability to revise and correct their first answer was analyzed with a direction of change analysis in the conflict trials (Bago & De Neys, 2017) to measure the percentages of participants able or unable to correct themselves after deliberation and those who were stable across the two generation steps (first idea in the fixation or expansion path and subsequent deliberation ideas stayed in the same solution path).

Third, to investigate the participants' ability to detect the conflict between their provided biased answer and the expected creative answer, their confidence in their first idea was compared between the conditions. This analysis procedure followed the one used by Bago and De Neys (2017), and only the participants who generated a first idea in the fixation path in both conditions were retained for this analysis.

Finally, in the CC, when asked to generate creative ideas, the participants' confidence in the creativity of their answers was compared between the answers provided in the biased (i.e., fixation) solution path and those provided outside it (i.e., expansion). This analysis allowed us to measure participants' ability to detect conflicts between biased (i.e., fixation) and non-biased (i.e., expansion) answers.

Results

Response distributions

The participants who did not generate an initial idea within the 10-second time limit or who generated a single idea in the overall task, which prevented comparison of the nature of the first answer to the overall behavior in the task, were excluded from the subsequent analyses since the results obtained during the first and second phases could not be compared ($n = 21$).

First, we investigated the prevalence of the first intuitive answer provided under time pressure in each solution path (i.e., fixation or expansion) (Table 1). As expected, analysis of the first response revealed a strong fixation effect: 92% of the responses belonged to the fixation solution path in the CC. The key finding, however, was that 8% of the initial responses provided in the CC belonged to the expansion solution path. Interestingly, the proportions of fixation (93%) and expansion (7%) answers were similar in the NC. This result suggests that some participants can provide an intuitive creative response, whether creative or classic, even when they are asked to solve a problem under time pressure.

Table 1. Percentage of initial ideas in the fixation or expansion paths according to the condition (CC = conflict condition; NC. = no-conflict condition).

	NC	CC
Fixation	93	92
Expansion	7	8

Response direction of change analysis

Given that the raw percentage of intuitive creative responses was not fully informative, we performed a direction of change analysis on the conflict trials (Bago & De Neys, 2017) to obtain deeper insight into the results of creative intuition. Consequently, the change in the participants' response after the deliberation phase was analyzed. The participants could provide a response belonging to the fixation or expansion in each of the two-response paradigm stages; therefore, there were four possible answer change patterns: responses within the fixation path in both steps (FF), responses within the expansion path in both steps (EE), an initial response within the fixation path and at least one expansion response generated during the deliberation step (FE), and an initial response within the expansion path and only responses within the fixation path generated during the deliberation step (EF). According to the traditional corrective dual-process assumption, participants were expected to give either FF responses, meaning that they provided a response within the fixation path in the first step and did not correct it in the second step, or FE responses, meaning that they initially generated a response within the fixation path, but after deliberation, they overcame fixation and provided a more creative response within the expansion path. Table 2 shows the direction of change category frequencies for the conflict problems. The majority of responses were FF (32.2%) and FE (60.09%) responses, which is in accordance with the corrective predictions. However, nonnegligible percentages of EE responses (5.29%) and EF responses (2.4%) were found, which is surprising and problematic from the corrective perspective.

Taken together, these findings suggest that providing a creative response (i.e., expansion solution) generally requires correcting the initial intuitive response influenced by fixation. However, some individuals can also generate an intuitive response that is already creative in nature without needing further deliberation.

Confidence scores and conflict detection in the first generation step

To measure the participants' conflict detection skills, we used analytical methods comparable to those

Table 2. Percentage of participants' direction of change according to the nature of their provided answer (fixation vs. expansion) and the generation step (first or second step) in the CC.

		Second step		
		Fixation	Expansion	Total raw
First step	Fixation	32.21	60.10	92,31
	Expansion	2.40	5.29	7,69
	Total column	34,61	65,39	

used in the two-response paradigm previously presented in the field of reasoning (Bago & De Neys, 2019a).

The first analysis focused on the participants' confidence in the relevance of the first response generated (i.e., Step 1) by contrasting the CC and NC. Since the focus of this analysis was biased answers, we removed the participants who provided a first response within the expansion path in the CC or NC from the analysis ($n = 29$). As expected, the analysis revealed that the participants were more confident in their first biased ideas in the NC ($M = 5.41$; $SD = 1.78$) than in the CC ($M = 2.99$, $SD = 1.80$; $t(178) = 11.3$, $p < .001$, $d = 0.85$; Figure 4a).

Confidence scores and conflict detection according to the nature of the answer

The second analysis examined the extent to which the participants were able to discriminate biased responses from more creative responses within the same creative task (i.e., CC). The focus of this analysis was the participants' confidence in the creativity of the answers they gave for all the ideas generated in the CC, whether fixation or expansion. Thus, only the participants who provided answers in both the fixation and expansion categories were included ($N = 66$). A t test analysis revealed that the participants were more confident in the creativity of their expansion ideas ($M = 4.26$; $SD = 1.69$) than in that of their fixation ideas ($M = 3.41$, $SD = 1.25$; $t(110) = 6.26$,

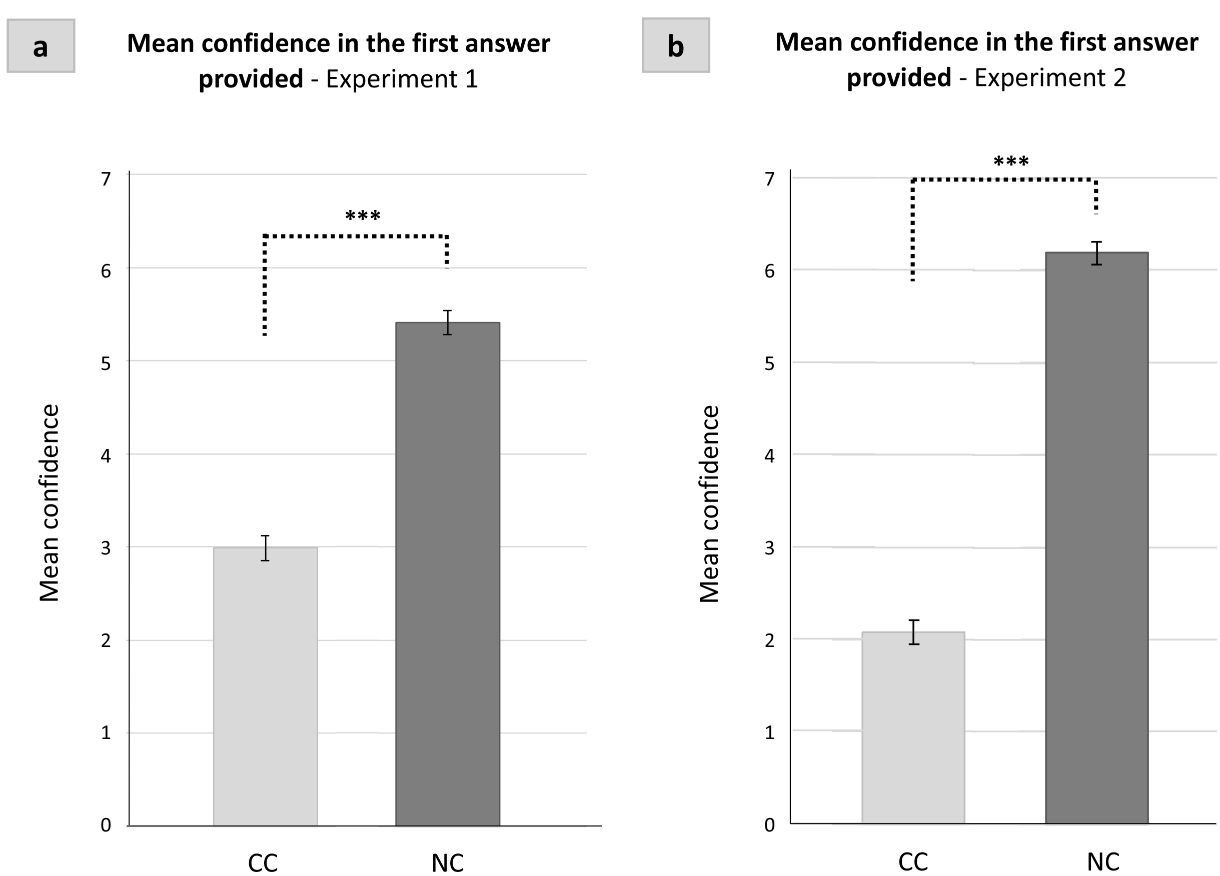

Figure 4. Mean confidence in the first answer provided according to the condition (CC = conflict condition; NC = no-conflict condition) for the participants in the first experiment (a) and second experiment (b), *** indicates that the statistical p value is < 0.001.

$p < .001$, $d = 0.59$). Thus, this finding suggests that the participants were able to discriminate their own biased ideas from their more creative ideas when asked to be creative (Figure 5a).

Discussion

The aim of this first experiment was to determine whether design novice adults are intuitively biased when they solve creative problems, leading to a fixation effect, and whether they can detect that their initial biased answers are less creative. Using an adaptation of the dual-response paradigm (Bago & De Neys, 2019a; Bago et al., 2019), the participants were asked 1) to provide the very first solution that came to their minds when trying to solve either conflict or no-conflict problems under time pressure and 2) to provide as many creative solutions as they could during a longer deliberation phase. Four major results emerged from the first experiment: 1) In the first step, while the vast majority of the participants provided a response within the fixation solution path, some succeeded in generating an original idea belonging to the expansive solution path. 2) The participants were able to correct their initial biased responses after deliberation. 3) The participants' confidence in their biased intuitive first responses was greater for the NC than for the CC. 4) In the second step, the participants were able to discriminate both types of solutions and were less confident in their fixation ideas (judged as less creative) than in their expansion ideas.

These findings support a dual-process model that stresses the intuitive nature of ideas under the fixation effect (Cassotti et al., 2016a). A vast majority of the responses provided under time pressure were within the fixation solution path. However, some participants succeeded in providing creative ideas during this initial response step even under the time constraint, which was supposed to reduce the activation of the deliberative System (Bago & De Neys, 2017). Although the intuitive nature of these *creative intuitions* requires further investigation using, for example, a dual-task paradigm coupled with cognitive load to experimentally suppress deliberative resources during the initial phase, our results here are consistent with previous findings in the fields of reasoning and decision-making (Białek & De Neys, 2016; De Neys et al., 2014; Lanoë et al., 2017; Raoelison, Boissin, et al., 2021). At least some participants can generate creative solutions intuitively.

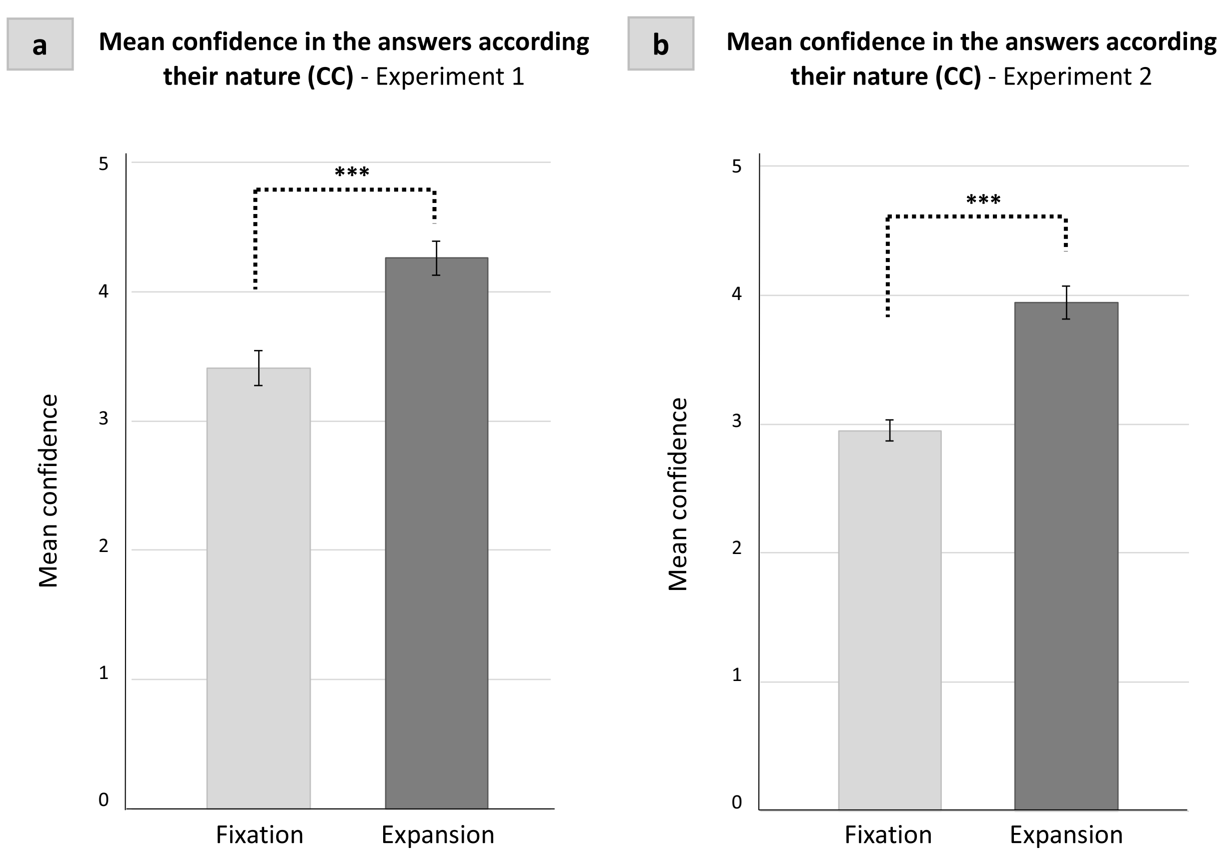

Figure 5. (a) Mean confidence in the first answer provided according to the experimental conditions. (b) Mean confidence rating in the answers provided in the CC condition according to their nature. *** indicates that the statistical p value is < 0.001.

A careful examination of the participants' ability to differentiate the creativity levels of their responses depending on whether the idea belongs to the fixation or expansion solution path revealed that the participants differentiated between the two response categories during the deliberation step. They judged the solutions generated within the fixation path to be less creative than those generated in the expansion path (i.e., solution categories outside fixation). These findings suggest that conflict detection, as observed in the fields of reasoning and decision-making, also exists in creative problem solving.

However, there are uncertainties about how sensitivity to fixation bias and conflict detection might change with expertise in adulthood. Experts in creativity and innovation might perform differently from novices in creative tasks requiring the individual to overcome a fixation bias. Previous investigations have supported this assumption by showing that the exploration of creative solutions is also impeded by the fixation effect in creative experts, such as industrial designers (Crilly, 2015; Linsey et al., 2010; Purcell & Gero, 1996; Viswanathan & Linsey, 2013) or engineers (Agogué et al., 2015; Camarda et al., 2017). For example, Agogué et al. (2015) reported that engineers and industrial designers differed in their ability to propose creative ideas for the egg task. Both groups exhibited fixation effects, although the industrial designers were less fixed and provided more expansive solutions than the engineers did. However, the introduction of an uncreative example reinforced the fixation effect and dramatically constrained their ability to overcome fixation. However, this study involved students in engineering or industrial design master's programs and not experts working in organizations or industries. While previous studies have suggested that experts in design and creativity may outperform novices in creative situations involving fixation bias, other research in the fields of reasoning and decision-making has suggested that experts can also exhibit greater susceptibility to cognitive biases.

For example, Reyna et al. (2014) demonstrated that a well-known decision-making bias was reinforced in intelligence agents, who are known to have professional expertise in decision-making, compared with college students. In classical framing effect studies, participants are exposed to options and risky gambles framed in terms of either gain or loss. A decision bias corresponds to the tendency to choose differently according to how the options are presented: risk aversion in the gain frame and risk seeking in the loss frame. By using this task, Reyna et al. (2014) showed that experts not only exhibited a greater framing effect than students did but were also more confident in their decisions. Contrary to traditional and common sense assumptions about the development of cognitive capacity, these results suggest that both overcoming decision bias and the ability to detect that the biased decision was not accurate (i.e., conflict detection) might be impaired in experts compared with students.

In this context, the purpose of Experiment 2 was to test the robustness of the findings of Experiment 1 and to examine whether a fixation effect in creative problem solving and conflict detection occur in experts of design and its management.

Experiment 2

The aim of the second experiment was to examine whether expert in design can detect when they are fixated on uncreative responses that are not relevant when they performed a creative task.

To do so, two new groups of participants were asked to complete generative problem-solving tasks (conflict and no conflict) using the adaptation of the two-response paradigm developed in Experiment 1. To test whether being an expert in doing or orienting design processes differently influences the fixation effect and conflict detection, engineers from the design field and design team managers from different industries were recruited.

On the basis of the results obtained with novice participants in Experiment 1, we developed the following hypotheses:

H1: The first intuitive response should belong to the fixation path in both the conflict and no conflict conditions.

H2: Some participants should provide intuitive creative responses (i.e., expansion) in the initial phase.

H3: With respect to conflict detection, participants should exhibit lower confidence in the relevance of their responses in the CC than in the NC.

H4: Participants should discriminate the creativity level of their responses depending on whether the response belongs to the fixation or expansion solution path in the CC.

H5: According to results showing that experts exhibit both greater decision biases and greater confidence in their irrational decisions (Reyna et al., 2014), we hypothesize that experts in design and innovation exhibit a greater fixation effect and a lower ability to detect that their nonoriginal fixed ideas are less creative.

Method

Participants

In total, 92 experts (29 working engineers and 62 design managers) participated. The participants were recruited from a network of industrial design partners associated with the research Chair Design Theory and Methods for Innovation of Mines Paris – PSL (a French school of engineering) and were employed with various companies: Airbus, CayaK-Innov, Nexter, Nutriset Group, Renault, SAB, Safran Group, SNCF, SPooN AI, STMicroelectronics, Tigres investissements, URGO, and ZAL.

The demographic information of each group (engineers and managers), including sex, mean age distributions and highest level of education, are presented in Table I in the supplementary material.

Tasks and procedure

Each participant was asked to complete the experiment online using Qualtrics software. The materials and procedures used in Experiment 2 were identical to those used in Experiment 1, except that the participants were also asked to complete additional questionnaires to better characterize the specificity of each group. Given that the sample of experts in design comprised engineers and managers, we evaluated whether they differed in their level of everyday creative achievement and specific expert abilities.

Measures of homogeneity between engineers and managers

In these questionnaires, the participants provided information about their highest level of education. Given that all the participants were workers, they were asked to use a Likert scale ranging from 1 (no expertise at all) to 10 (high expertise) to report their perceived expertise in three domains relevant to the design industry that could distinguish the work of engineers and managers: 1) experience in decision-making, 2) experience in team management, and 3) experience in design performance.

Finally, to evaluate whether the two samples differed in their personal and everyday creative activities and creative achievements, all participants completed a short version of the Inventory of Creative Activities and Achievements (ICAA; Diedrich et al., 2018). This scale is used to evaluate involvement in everyday creative activities (CAct) and creative achievements (CAch) within 8 domains: literature, music, arts and crafts, creative cooking, sports, visual arts (graphics, painting, sculpting, and architecture), performing arts (theater, dance, and film) and science and engineering. For each domain, the participants were asked to indicate how frequently they performed certain activities in the past 10 years (*0 = never; 1 = 1–2 times; 2 = 3–5 times; 3 = 6–10 times; 4 = more than 10 times*). A CAct general score was computed by summing the CAct scores across the eight domains. For each domain, the participants were asked to report their level of attainment in each domain, ranging from *I have never been engaged in this domain* to *I have done some work in this domain*. Each level corresponded to an increasing value from *0 to 10*. A CAch general score was computed by summing the CAch scores across the eight domains.

Results analysis

As in the first experiment, the participants' conflict detection skills were investigated by analytical methods comparable to those used in the two-response paradigm previously presented in the field of reasoning (Bago & De Neys, 2019a).

We investigated the distribution of the nature of the first responses, the direction of change and participants' confidence in the relevancy of their first biased ideas (compared between both conditions) and in their fixation vs. expansion ideas (in the CC).

Moreover, the differences between engineers and managers were studied in terms of expertise in design, decision-making, and team management; everyday creativity and achievement (CAct, CAch); and creative performance in the creative problem-solving task presented.

We analyzed the ideas generated by the participants in the CC using classical measures from creativity studies. For each participant, we computed a fluency score (i.e., the number of overall ideas generated), a fixation score (i.e., the number of fixation ideas generated) and an expansion score (i.e., the number of expansion ideas generated).

Repeated-measures analysis of variance (ANOVA) was performed for the expertise indicators of individuals (design, decision-making and team management) and CAct and CAch scores to further explain the observed variability.

Similarly, we investigated the extent to which the two groups of experts differed in terms of creativity competence by running repeated-measures ANOVAs on the fluency, fixation and expansion scores.

Results

Analyses of the homogeneity of the expert sample

The analyses of the differences between managers and engineers in terms of their expertise and their everyday creative achievements are described in detail in the supplementary material.

The results revealed that managers reported more expertise than engineers did in team management and decision-making but tended to report less expertise in design conception. Moreover, the Student t tests did not reveal a significant difference in the CAct or global CAch scores between the two groups.

Analyses of creativity performance

Since the following analyses were performed to investigate the participants' creative performances, the total responses generated in the CC were analyzed. An ANOVA conducted on the fluency score revealed no differences between the numbers of ideas generated by the engineers and managers ($M_{Engineers} = 9.1$, $SD_{Engineers} = 3.8$; $M_{Managers} = 8.5$, $SD_{Managers} = 3.5$; $F(1, 90) = 0.66$; $p = .42$; $\eta^2 p = .007$).

To investigate the extent to which the generation of creative ideas was constrained by the fixation effect in experts and how it varied according to expert type, a repeated-measures ANOVA was conducted on the number of ideas generated with the nature (i.e., fixation or expansion) as a within-subject factor and the participant group as a between-subject factor. The results revealed a simple effect of the nature of the ideas, indicating that the participants generated more ideas within the fixation solution path than within the expansion solution path ($M_{Fixation} = 6.57$, $SD_{Fixation} = 2.43$; $M_{Expansion} = 2.15$, $SD_{Expansion} = 2.01$; $F(1, 90) = 138.98$; $p < .001$; $\eta^2\ p = .60$). The simple effect of participant group ($F(1, 90) = 0.66$; $p = .42$; $\eta^2 p = .007$) and the interaction between the idea nature and participant group were not significant ($F(1, 90) = 1.24$; $p = .27$; $\eta^2\ p = .01$).

All these results were robust and remained unchanged when controlling for experience in design conception, team management and decision-making; CAct score and CAch score in analyses of covariance (ANCOVAs). Since creative performance was similar between the engineers and managers for each measure, both groups were combined in subsequent analyses.

Response distributions

To compare the nature of the ideas provided during the first and second generation phases, the participants who did not generate an initial idea within the 10-second time limit or who generated a single idea in the overall task were excluded ($n = 4$). The nature of the first intuitive answer (i.e., fixation or expansion) provided under time pressure in each condition was investigated. As expected, analysis of the first response revealed a strong fixation effect (Table 3): 91% of the responses belonged to the fixation solution path in the CC. The key finding, however, was that 9% of the initial responses provided in the CC belonged to the expansion solution path. Interestingly, the proportions of fixation (93%) and expansion (7%) answers were similar in the NC. This result suggests that some participants can provide an intuitive creative response even when they are asked to solve a problem under time pressure.

Response direction of change analysis

As in the first experiment, we observed many FF (20.45%) and FE (70.45%) responses, indicating that individuals initially generated a fixation response and overcame it (FE) or did not overcome it (FF) during the deliberation step (Table 4). However, in contrast to the corrective hypothesis, a nonnegligible percentage of EE responses (9/09%) was found. Like the results of the first experiment, these findings suggest that requesting a creative response (i.e., expansion solution) allowed the participants to correct their initial intuitive fixation responses in the vast majority of cases. However, some individuals were also able to generate intuitive creativity without further deliberation.

Confidence scores and conflict detection in the first generation step

To analyze the participants' confidence in the relevance of the first response generated (i.e., Step 1) between the CC and NC, the participants who provided a first response within the expansion path in the CC or NC were included ($n = 11$). As expected, a repeated-measures ANOVA revealed that the participants were more confident in their first biased ideas in the NC ($M = 6.18$; $SD = 1.08$) than in the CC ($M = 2.08$, $SD = 1.17$; $t(76) = 19.4$, $p < .001$, $d = 2.21$; Figure 4b).

Table 3. Percentage of initial ideas in the fixation or expansion paths according to the condition (CC = conflict condition; NC. = no-conflict condition).

	NC	CC
Fixation	97	91
Expansion	3	9

Table 4. Percentage of participants' direction of change according to the nature of their provided answer (fixation vs. expansion) and the generation step (first or second step) in the CC.

		Second step		
		Fixation	Expansion	Total raw
First step	Fixation	20.45	70.45	90.91
	Expansion	0	9.09	9.09
	Total column	20.45	79.55	

Confidence scores and conflict detection according to the nature of the answer

The second analysis examining the extent to which the participants were able to discriminate their biased responses from their more creative responses focused on the participants' confidence in the creativity of the fixation or expansion answers they provided in the CC. Thus, the participants who were unable to provide both fixation and expansion answers were excluded from the following analysis ($N = 17$). A t test analysis revealed that the participants were more confident in the creativity of their expansion ideas ($M = 3.94$; $SD = 1.34$) than in their fixation ideas ($M = 2.95$, $SD = 0.84$; $t(57) = 6.54$, $p < .001$, $d = 0.86$). This finding suggests that the participants were able to discriminate their ideas according to their biased and unbiased nature (Figure 5b).

General discussion

Increasing evidence supports the import of the dual-process model from the field of reasoning to the generation of creative ideas. According to this model, individuals who try to be creative in a generative problem-solving task can be biased by the initial System of thought (System 1; intuitive and automatic), which should be inhibited to activate a second System of thought (System 2; more logical, effortful, slower), leading to conceptual expansion (Camarda, Borst, et al., 2018; Camarda, Salvia, et al., 2018; Cassotti, Camarda, et al., 2016). However, the field of reasoning has provided substantial evidence that although participants can be biased when solving complicated problems, they are able to detect their biases (Bago & De Neys, 2019a; De Neys, 2014; De Neys & Pennycook, 2019). This function, called conflict detection (i.e., the ability to detect that a biased answer can be wrong and conflict with the expected answer in the task), appears to be a key element in engaging in cognitive control and overcoming reasoning biases to achieve an unbiased response (Bago & De Neys, 2019a, 2019b; Bago et al., 2019; Raoelison & Neys, 2019; Raoelison, Boissin, et al., 2021). Thus, the parallel between the models proposed in the reasoning field and the creativity field has led us to investigate 1) whether conflict detection may be involved in the creativity process when individuals are required to overcome the fixation effect and 2) whether this competence may be related to design expertise. Therefore, two experiments were performed, one in which the participants were novices in design processes and one in which the participants were two groups of design experts (engineers and managers).

The first major finding was that when asked to provide their initial ideas, the participants were extremely biased, regardless of their expertise. In total, 93% of the novices and 97% of the experts provided an initial idea in the fixation solution path. These results indicate that when individuals are asked to provide an initial idea under an experimental paradigm that is believed to reduce accessibility to System 2 and maximize the use of System 1 by adding time pressure (Bago & De Neys, 2019c; Bago et al., 2019), fixation answers are common. This finding indicates that the fixation solution path is the first path accessed by individuals, and its inhibition seems to require non-automatic functions that are accessible only in a second-step process (Bago et al., 2019; Camarda, Borst, et al., 2018; Cassotti, Agogué, et al., 2016; De Neys & Pennycook, 2019). This result provides new support for a dual-process model of creativity in which a first System of thought induces individuals to lazy exploration of the path of least resistance (Allen & Thomas, 2011; Barr et al., 2015; Cassotti, Camarda, et al., 2016; Dorfman et al., 2008; Ward, 2007). Moreover, the fact that the novices and design experts performed similarly when they were asked to complete a generative creative problem-solving task intuitively corroborates Kahneman's observations that biases are present in everyone, whether novices or experts (Kahneman, 2003; Kahneman & Frederick, 2007; Kahneman & Klein, 2009). Corroborating the predominance of System 1, the number of fixation answers provided exceeded the number of expansion ideas during the overall generation process of creative ideas in both experiments. Additionally, the results of the analysis of the participants' fluencies and the number of ideas generated in fixation and expansion during the overall conflict task (i.e., when asked to be creative) were similar regardless of their level of expertise in design, team management, or decision-making.

The second main observation was that some participants from each sample were endowed with a form of creative intuition, since they offered a spontaneous unbiased and creative response even under time pressure, which is supposed to restrict access to System 2. These results corroborate those observed in numerous studies that have investigated detection abilities in other domains, particularly reasoning (Bago & De Neys, 2019a, 2019b; Bialek & De Neys, 2017; De Neys et al., 2008, 2014; Frey et al., 2018; Janssen et al., 2020; Lanoë et al., 2017; Mevel et al., 2019; Raoelison, Boissin, et al., 2021). Interestingly, only 9% of the experts were able to provide an initial intuitive answer on the expansion solution path. This result provides a new challenge to studies of the naturalistic decision-making approach, which are interested in the elements distinguishing experts from nonexperts and have shown that experts have highly relevant spontaneous intuitions but novices do not (Kahneman & Klein, 2009; Klein et al., 2017). For example, expert chess players are able to intuitively determine the most interesting moves, whereas novices consider many other solutions, all of which are far less relevant. In addition, nurses have been shown to be able to intuitively identify pathologies in children, even when they are not yet clinically apparent (Kahneman & Klein, 2009; Klein et al., 2017). However, our results demonstrate that very few experts in design can intuitively overcome the fixation solution path. This result appears more consistent with recent findings that a form of expertise that is acquired through training paradigms that require participants to simply repeatedly complete complicated problems without (Raoelison & Neys, 2019; Raoelison, Keime, et al., 2021) or with feedback (Janssen et al., 2020) is not sufficient to improve the participants' performance in terms of intuitive bias. Certain forms of training tested recently could still promote stimulation of conflict detection and the emergence of logical intuitions in the field of reasoning. Boissin et al. (2022) demonstrated that offering a training session during which participants were told which path to follow to find the correct answer but which actually led to a typically incorrect answer for each problem stimulated conflict detection and generated logical responses in the first phase of solution generation (under time constraints). Thus, similar meta-cognitive training could be associated with the ability to overcome biases, as previously demonstrated in the field of reasoning (Boissin et al., 2022; Houdé & Tzourio-Mazoyer, 2003). In the field of creativity, a recent trend has demonstrated a link between the creative performance of individuals and their meta-cognitive skills (Lebuda & Benedek, 2024). This trend suggests that meta-cognitive training in defixation, such as that carried out by Boissin et al. (2022), could be beneficial, including in creative problem solving. However, it would be interesting to further analyze the profile of individuals who respond spontaneously with an expansion answer. Although expertise does not seem to be a divisive factor, our results do not allow us to explore this question in greater depth because very few participants produced an initial expansion idea. Future studies should attempt to reproduce our results in a much larger sample to maximize the number of participants who start with an expansion idea and to deepen our understanding of the characteristics of these persons (i.e., expertise, age).

The third main result of this study was that the participants doubted the relevancy of their fixed intuitive answers when they should inhibit them since these solutions are not relevant (i.e., CC) more often than when the solutions appear relevant (i.e., NC) according to the initial statement. Thus, both novices and design experts were able to detect conflicts. This result is consistent with previous findings in the reasoning domain (Bago & De Neys, 2019a, 2019b; Bialek & De Neys, 2017; De Neys et al., 2014; Frey et al., 2018; Janssen et al., 2020; Lanoë et al., 2017; Mevel et al., 2019; Raoelison, Boissin, et al., 2021) and demonstrates that being able to discriminate one's bias is not a skill reserved for design experts.

Finally, the participants were also able to discriminate their biased and nonbiased answers within a creative task, regardless of whether they were novices or experts. Participants felt more confident in the relevancy (i.e., creativity) of the answer they provided in the expansion solution path than in those provided in the fixation solution path. This result provides evidence of the stability of individuals' conflict detection abilities across conditions and within a given task. Taken together, these last two major results corroborate previous results, demonstrating that adults are able to discriminate their own biased answers (Bago & De Neys, 2019a, 2019b; Bialek & De Neys, 2017; De Neys et al., 2014; Frey et al., 2018; Lanoë et al., 2017; Mevel et al., 2019). However, this study is also the first to demonstrate conflict detection abilities in a creativity task and, more broadly, during a task in which there is more than one good answer. Previous studies used paradigms in which the proposed reasoning tasks required overcoming a biased (wrong) answer to achieve an unbiased (right) answer, as described previously in the bat and ball problem (Bago et al., 2019, Bago & De Neys, 2019a; Frederick, 2005; Raoelison & Neys, 2019). In the generative problem-solving task proposed in our two experiments, no answer proposed by the participants was wrong or right. The distinction between the responses generated in fixation and in expansion was characterized only by their adequacy for meeting the expectations of the task and the value of the idea generated. Thus, a fixation response is not wrong but is not as creative as an expansion idea.

This "no wrong answer" paradigm highlights the fifth major result of our study: a vast majority of the participants were able to revise their initial wrong answers, which is a novel finding in the literature. More than 60% of the novice participants and more than 70% of the experts were able to revise their initial fixation ideas and provide at least one expansion idea in the second step of the generation. This result is consistent with the corrective dual-process assumption suggesting that individual initial intuitive responses are biased but can be corrected after deliberation. However, it contradicts findings from the reasoning field that individuals are stable across steps and poorly able to revise their initial biased answers. In paradigms involving good/bad answers, only 10% of participants corrected their initial biased (incorrect) answers to provide unbiased (correct) answers. Moreover, stability was demonstrated for a greater proportion of participants who provided both initial and final biased answers (more than 50%) or initial and final unbiased answers (30%; Bago & De Neys, 2017, 2019b; Thompson et al., 2018). The parallel findings between the double-process theories in the domains of reasoning and creativity suggest that a major difference between conflict detection in both domains may be associated with the truth status of the bias. The major results that we observed in terms of correction may be associated with this specific point. However, our results corroborate those of Bago et al. (2020), who also observed a deviation from the poor corrective assumption arising from reasoning experiments (such as the bat and ball problem) by focusing on conflict detection in the field of fake news, which also supposes true or false propositions. Future studies should investigate which problem characteristics (convergent, divergent, ill-defined) allow individuals to correct themselves instead of following an initial biased response.

Limitations

Surprisingly, the novices and experts seemed to perform similarly on each task. Moreover, to examine the impact of specific expertise on the ability to overcome and detect the fixation effect in more depth, two groups of experts were investigated: engineers and managers who work in design industries and teams. As expected, the engineers reported more expertise in design than did the managers. Conversely, the managers were more accustomed to orienting design processes and rated themselves as having more expertise in decision-making and team management than the engineers did. However, their expertise in design, decision-making and team management did not significantly impact the nature of their intuition or their ability to detect conflict. Thus, while the two groups of experts perceived themselves as different, they behaved in the same way. Our results did not show any notable differences between the performances of the three samples. The relevancy of the expertise that was chosen may be in question. The expert groups were selected because 1) their expertise relied on their work environment, namely, the design sector, and 2) they had more specific expertise in doing (i.e., engineers) or orienting (i.e., managers) the design process.

There are two explanations for why the novices and experts performed similarly. On the one hand, studies from the field of reasoning have provided evidence that conflict detection abilities develop during childhood and adolescence and do not seem to evolve with age (Rossi & De Neys, 2020; Rossi et al., 2013). Thus, this cognitive function might not evolve after entering adulthood. The second hypothesis explaining the absence of any expertise effect could be related to the type of expertise investigated. The proposed tasks did not directly relate to the expertise of the participants in the sense that they were not targeted to a particular area of knowledge. In this sense, this limitation is important because it has been shown in the literature that the effects of expertise can arise from the specificity of experts' areas of knowledge (Amabile, 1982; Kaufman et al., 2009). Thus, the type of expertise evaluated in this manuscript could be too abstract. Kahneman and Klein (2009) reviewed the literature to investigate the extent to which expertise could be beneficial in developing a nonbiased intuition, such as that demonstrated by expert chess players or nurses. According to the authors, the fundamental element needed to develop expertise is a work environment that is sufficiently stable to allow the repetition of specific learning opportunities. Thus, the more repetitive a task is, the greater the degree to which it allows significant learning and expertise. Therefore, the profiles of the participants we selected as experts clearly demonstrate the complexity of the underlying work tasks. Although the managers were more specialized in team management and decision-making, they also reported being involved in design tasks. Similarly, although the engineers reported being specialized in design, less specialized in management, and even less so in decision-making, they also reported being involved in each of these tasks. Future studies should investigate the extent to which creative intuitions can develop depending on specific areas of expertise and on specific vs. abstract work tasks.

The multivariate approach to creativity hypothesizes that creativity potential can be influenced by many cognitive and conative factors. Among the variables that could modulate creativity are the domain and nature of the task (e.g., divergent thinking, convergent thinking; Lubart et al., 2013). However, dual-process models adapted to the creativity field, such as the triadic model of creativity, do not yet consider these specificities. In this context, investigating the extent to which conflict detection skills are specific to a given task and a given context in the general population and among experts would be interesting. Thus, future studies should attempt to replicate the results of the two experiments presented in this article while proposing an experimental protocol within which the nature of the task and its domain could vary.

Finally, it is important to highlight two limitations of our study related to the construction of the experimental paradigms. First, the level of everyday creativity (general and specific) and expertise in design, team management and decision-making were investigated for the study, which focused on experts (Experiment 2). The creativity level was measured by questions answered by the participant during the demographic data collection phase before their completion of the divergent problem-solving tasks. It is possible that these questions could modulate a participant's ability to complete divergent problem-solving tasks because of phenomena such as the stereotype threat (Dumas et al., 2016). According to this theory, the creativity skills of participants who gave themselves high scores on a characteristic linked to creativity (i.e., design) could be stimulated. Although participants' answers to these questions did not impact their performance in terms of creativity (fluency score, fixation and expansion), future studies should avoid those potential biases and ask participants about their expertise and everyday creativity after completing the experiment. Moreover, everyday creativity achievement and expertise measures were not accounted for in Experiment 1. Although these measures did not seem to have a significant impact on experts in creativity skills, it would still be interesting to investigate their impacts in the general population. Because the sample for our first experiment was composed of students and workers, it would have been interesting to investigate the impact of entry into working life on the evolution of the conflict detection phenomenon.

Practical implications

In our society, industries are in constant competition and face numerous societal crises, which require them to reinvent themselves and innovate rapidly. This time constraint may harm the creative process of employees since managing crises reduces the time available to managers (and their teams) for actions with limited short-term benefits. In these situations, creative people are rushed and must quickly develop innovative solutions. However, as shown by our results, when individuals face a divergent problem-solving task under time constraints, the initial responses are mostly biased and less creative. Individuals need time to initiate creative thought processes, overcome their initial biases and correct themselves. These findings suggest that organizations wishing to stimulate the creativity and innovation of their employees should protect the creative process and the need to take time to generate new ideas, avoid haste and improvisation, and open spaces for discussion over time.

Furthermore, although more in-depth studies are necessary to investigate the forms of expertise that could promote the emergence of more creative intuitions, the results show that innovation experts such as managers and engineers are capable of conflict detection as novices. The first practical implication that follows from this result is that practices such as including both experts and novice citizens in the codesign of innovative solutions to societal problems may be helpful, more so if we consider that mixing knowledge and skills in a collective thinking group can be beneficial for everyone. Furthermore, this result underlines the importance of feeling doubt. Since doubt is a shared feeling, everyone can rely on it to determine the blockages that we encounter in the generation of creative solutions and to inhibit these blocks to activate other categories of innovative solutions.

Conclusion

The two experiments presented above aimed to determine the extent to which biases in the generation of creative ideas occur spontaneously and to what extent they can be detected and corrected after a deliberation phase according to the individual's design expertise. Through the adaptation of a two-response paradigm used in the reasoning field for many years, our findings demonstrate for the first time that design novices and experts are spontaneously biased by heuristic responses but are also able to discriminate biased from unbiased responses. Moreover, the two-response paradigm was proposed for the first time in a study using problems for which no solution was true or false and thus challenges the models in the reasoning field. As opposed to reasoning problems, in which individuals very rarely manage to correct their initial biased responses, the participants in our two experiments were able to correct themselves in most cases (more than 60%). Thus, beyond being able to detect their own biases, individuals are also able to correct themselves, especially in situations in which the exploration of different elements is allowed.

The cognitive capacities and limits (in particular, cognitive biases) of experts and engineers remain very poorly studied. Some studies suggest that experts are not affected by any biases that affect student samples, or vice versa. However, our studies demonstrate an important parallel between novices and experts in the constraints exerted by cognitive biases as well as the ability to detect and overcome these biases. We cannot exclude that novices and experts behave differently in terms of solving problems for which knowledge is accessible with only a certain level of expertise. However, although the engineers and managers in our samples had skills, knowledge and methodological design expertise that novices did not have, the cognitive mechanisms allowing the generation of creative ideas and their limits are comparable in both groups.

Although our study was not conducted directly within the participants' companies, managerial implications can be drawn from our results. Importantly, no difference was found in the behaviors of engineers and expert design managers. In other words, despite a specificity of expertise (in design, team management, or decision-making), both groups were biased during their generation of creative ideas and capable of detecting their biases and correcting themselves. Thus, within a team composed of individuals with similar or mixed profiles, individuals' conflict detection capacities appear to be a key component in overcoming fixation bias, which is one of the most important factors impeding creativity and radical innovation. Therefore, our results suggest the importance of additional studies focused on the skills and cognitive limits of engineers and managers and relying on cognitive models validated with student samples to develop our understanding of these practices.

Note

1. Note that the hole task, the light task, and the door task were pre-tested in a sample of young adults in order to 1) create a C-K tree representing a mapping of all possible categories of solutions used to solve each problem, and 2) determine the nature of the fixation effect. Before coding the ideas generated by participants in the present study, the rater practiced on a subsample of the ideas collected during the pretest. In the event of a coding error or misunderstanding, the rater could rely on previous coding examples from this practice phase.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The preparation of this article was supported by a grant from the French National Research Agency (ANR-18-CE26-0013-01 AppLeaC).The opinions expressed in this publication are those of the authors and do not necessarily reflect the view of the funding agency.

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Data availability statement

The data that support the findings of this study and supplementary material are openly available in https://osf.io/u4jmv/.

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