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The Mechanism of the Einstellung (Set) Effect: A Pervasive Source of Cognitive Bias

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Abstract

The eye movements of expert players trying to solve a chess problem show that the first idea that comes to mind directs attention toward sources of information consistent with it and away from inconsistent information. This bias continues unconsciously even when players believe they are looking for alternatives. The result is that alternatives to the first idea are ignored. This mechanism for biasing attention ensures a speedy response in familiar situations, but it can lead to errors when the first thought that comes to mind is not appropriate. We propose that this mechanism is the source of many cognitive biases, from phenomena in problem solving and reasoning to perceptual errors and failures in memory.

Keywords

cognitive bias, Einstellung (set) effect, problem solving, chess, expertise

Four centuries ago, Francis Bacon pointed out the unfortunate human tendency to ignore new evidence that could undermine a firmly held opinion (Bacon, 1620/1939; p. 36). Little has changed. Tetlock (2005) found that expert political scientists do not change their theories when events prove their predictions wrong; they keep the theories and discount the evidence. Similarly, Stephen Jay Gould (2006) showed that scientists can be so strongly influenced by the theory they already hold that they do not interpret new data objectively. The experts' theories were originally based on an accumulation of evidence, so it is not that they cannot absorb new information. The question is: Why, once a point of view has been formed, do people find it difficult to assimilate new information if it is not consistent with the view already held?

The answer is suggested by recent studies of the Einstellung (mental-set) effect—the fixation of thought produced by prior experience—which demonstrate that effect's power and reveal its mechanism (Bilalić, McLeod, & Gobet, 2008a, 2008b). Many cognitive biases that make it difficult for people to assimilate new evidence may have their origin in a similar mechanism to that which produces the Einstellung effect. The effect is particularly dangerous because people are unaware that they are affected by it. As Gould (2006) noted, "In most cases ... biases ... were unknowingly influential and ... scientists believed they were pursuing unsullied truth" (p. 59).

The Classical Einstellung (Set) Effect

The Einstellung effect occurs when an idea that comes immediately to mind in a familiar context prevents alternatives being considered. It was first experimentally demonstrated by Luchins (1942). He gave people a series of problems that could be solved by a fixed method that they quickly learned. Then he gave them a problem that could be solved using the usual method but also with a different, quicker one (thus called the 2-solution problem). Most of the participants continued to use the old method, not spotting the quicker alternative. This is perhaps unsurprising given that the old method had proven effective. However, when participants were presented with a final problem (called the 1-solution problem), apparently similar to the previous ones but for which the familiar method now did not work and there was only one solution method possible, many of the participants said that that this new problem was insoluble. In fact, it could be solved using the shorter method from the previous problem. The fixation of thought displayed by these people was demonstrated by a control group who were given

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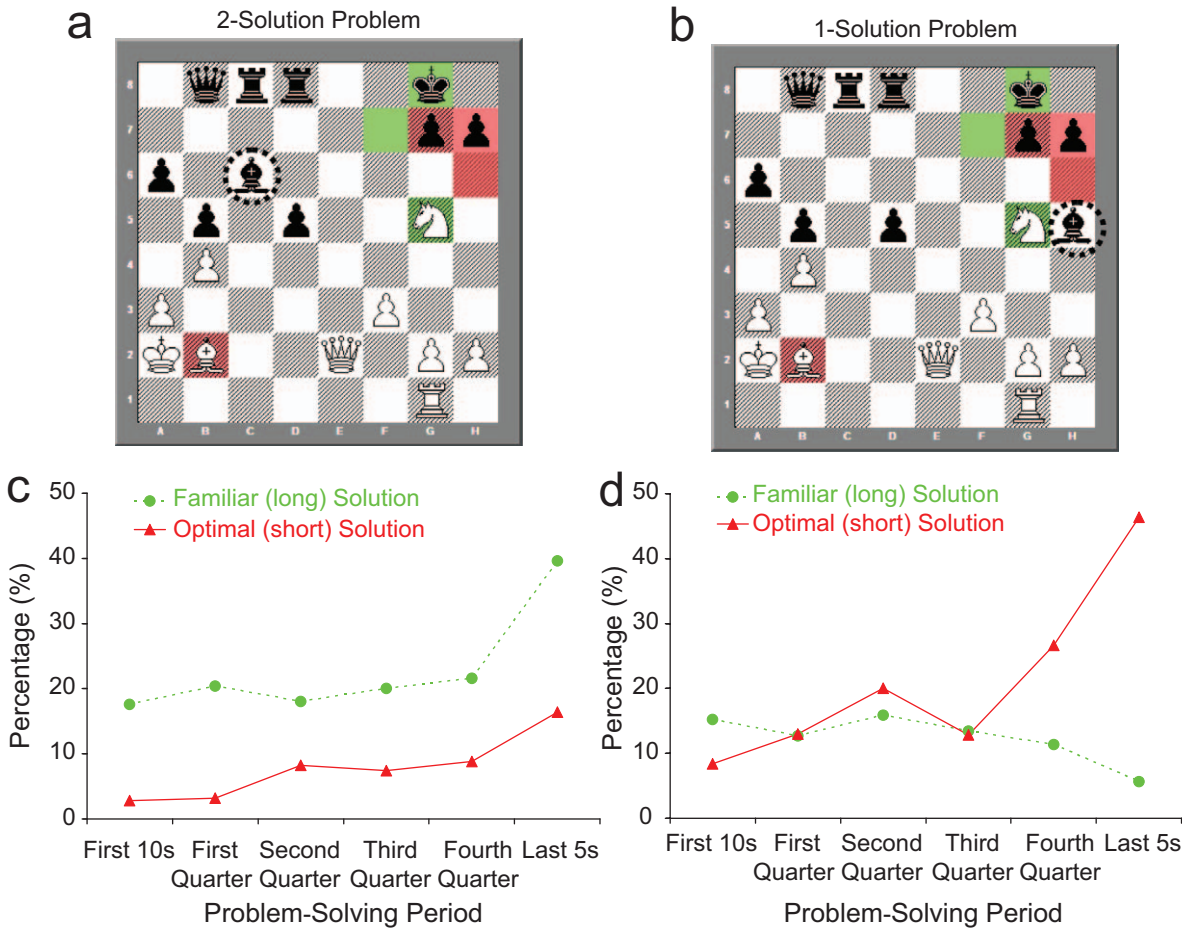

Fig. 1. Two variants of a chess scenario used in Bilalić, McLeod, and Gobet (2008b). In both problems (which are based on an idea by Saariluoma, 1990), players were instructed to find the shortest way for White to win the game. The longer solution available in the 2-solution problem (a) is a "smothered mate," familiar to expert chess players (1. Qe6+ Kh8 2. Nf7+ Kg8 3. Nh6++ Kh8 4. Qg8+ Rxg8 5. Nf7 mate), but there is also a shorter solution that is less familiar (1. Qe6+ Kh8 2. Qh6! Rd7 3. Qxh7 mate, or 2. . . . Kg8 3. Qxg7 mate). The arrangement of pieces on the board in the 1-solution problem (b) is the same as in the 2-solution problem except that Black's bishop (circled) is on h5 rather than c6; in this variant, smothered mate is now no longer possible because Black's bishop covers f7, but the shorter solution is still possible (1. Qe6+ Kh8 [if 1. ... Kf8 2. Nxh7 mate] 2. Qh6! Rd7 3. Qxh7 mate, or 2. . . . Kg8 3. Qxg7 mate, or 2. . . . Bg6 3. Qxg7 mate). The squares crucial for the longer, smothered-mate solution but not for the shorter one are highlighted in green (f7, g8, & g5) and those crucial for the shorter solution but not the longer one in red (b2, h6, h7, & g7). The percentage of time in different phases of problem solving that the experts (Candidate Masters) tackling the 2-solution problem spent looking at squares crucial to the familiar smothered-mate solution (green color) and shorter solution (red color) are shown at the bottom left (c). (For each player, the first 10 seconds and the last 5 seconds before announcing the solution were analyzed separately; the remaining period, of whatever length, was divided into four equal periods.) The lower right graph (d) shows the percentage of time the experts looking at the 1-solution problem (in which the familiar longer solution was disabled) spent looking at the crucial squares for the longer and shorter solution.

only the 1-solution problem. They solved it quickly, showing that the problem was not intrinsically difficult. The experimental group failed to find the solution because the similarity of the final problem to the previous ones brought the usual (but now inappropriate) method to mind, blinding them to alternatives.

The Einstellung Effect in (Chess) Experts

We recently showed that the Einstellung phenomenon can not only be demonstrated with laypeople and simple logical problems but also with experts and complex problems (Bilalić et al., 2008b). We showed the position in Figure 1a to expert chess players and asked them to find the shortest solution. This is a 2-solution problem just as in the Luchins (1942) study. One solution is a five-move sequence leading to a smothered mate. The smothered-mate sequence is well known to all good chess players, and the possibility that it could be used in this position was quickly noticed by all the players. The second solution is less familiar but shorter, leading to mate in three moves. Players spoke aloud as they tried to solve the problem. All players

Table 1. Percentage of Stronger and Weaker Players Finding the Best, Unfamiliar Solution in a Chess Problem

	Problem	
Skill level	2-solution[a]	1-solution[b]
Stronger players		
International Master (+5 SD)	50%	100%
Master (+4 SD)	18%	100%
Candidate Master (+3 SD)	0%	100%
Weaker players		
Class A (+2 SD)		63%
Class B (+1 SD)		13%
Class C (average)		0%

Note. Player strength is given in standard deviations (SDs) above the average for all chess players. [a]The 2-solution problem is a chess scenario having a familiar, longer solution in addition to the shorter, more optimal solution that is less familiar (see Fig. 1a for detailed description of the problem). [b]The 1-solution problem is similar but with the longer, familiar solution removed as a possibility; only the shorter, unfamiliar solution will work (see Fig. 1b). Weaker players were presented with the 1-solution problem only.

found the familiar solution quickly and then said they were looking for a shorter one. Those who failed to find it (and said that the smothered mate was the shortest solution) were then shown the 1-solution problem (Fig. 1b). This problem is the same as the 2-solution problem except that the familiar smothered-mate solution has been disabled by moving one piece, leaving only the shorter solution from the 2-solution problem. Hence, the 1-solution problem was similar to the last problem in the Luchins design, in which the participants' familiar solution would not solve the problem but an alternative method would. All players found the shorter solution in the 1-solution problem, showing that that solution was discoverable in the absence of a distracting, more familiar solution.[1]

Quantifying the Einstellung Effect

Previously the Einstellung effect has only been reported as a qualitative effect. With chess players it can be quantified, as the relative strength of different players is known precisely from their performance against other players of known strength. The scale has a mean of 1500 and a standard deviation (SD) of 200. Table 1 gives the names of different skill levels and their strength relative to average players in terms of the number of SDs they are above the average. We quantified the effect by comparing the performance of stronger players on the 2-solution problem with the performance of weaker players on the 1-solution problem. Across a range of skill levels, the presence of a familiar solution that first came to mind reduced the problem-solving performance of the experts to that of players about 3 SDs lower in skill: The performance of International Masters (5 SDs above average) on the 2-solution problem was comparable to that of Class A players (2 SDs above average) on the 1-solution problem, the performance of Masters (4 SDs above average) was comparable to that of the Class B players (1 SD above average), and the performance of Candidate Masters (3 SDs above average) was the same as Class C players (average). Experiments with different problems yield similar quantitative differences between the performance of stronger players on the 2-solution version of the problems and the performance of the weaker players on the 1-solution version of the problems (see Bilalić et al., 2008b).

The Einstellung effect is indeed very powerful—the chance of a player being beaten by a player 3 SDs lower in skill is close to zero. Yet that is the level to which the first idea that came to mind on seeing the position—the presence of a smothered mate—reduced the ability of the players to find another solution.

The Mechanism of the Einstellung (Set) Effect

Why did the players experiencing the Einstellung effect fail to find the less familiar solution? We measured the eye movements of two new groups of chess experts who were given either the 2-solution problem or the 1-solution problem (Bilalić et al., 2008a). This allowed us to see which squares the players were looking at and how long they spent looking at them as they tried to solve the problem. We used Candidate Masters (3 SD above average), and as in the previous experiment, none of the group shown the 2-solution problem (Fig. 1a) found the shorter solution while all the players shown the 1-solution problem (Fig. 1b) found it. Although all the players trying to solve the 2-solution problem said that they looked for a shorter solution after spotting the familiar smothered-mate solution, the eye movements, shown in Figure 1c, told a different story. The players' eyes continued to dwell on squares and pieces involved in the familiar smothered-mate solution (as shown by the green circles) throughout the time they believed they were looking for alternatives. They spent little time on the squares required to find the shorter solution (as shown by the red triangles). The group shown the 1-solution problem found the shorter solution without much difficulty. Initially, their attention, as measured by their eye movements shown in Figure 1d, was directed equally at squares and pieces involved in the solution and at those that were not. But shortly before announcing that they had discovered the solution, they started to focus on the key squares.

The eye-movement data demonstrate how a pattern of thought, once activated, can prevent other patterns of thought becoming active. As soon as a problem or situation is recognized as familiar, the knowledge (schema) for dealing with it is activated. The schema directs attention toward those aspects of the situation that are relevant to the schema and away from those that are not. Thus, the search for a solution becomes self-fulfilling, with information consistent with the already-activated schema being more likely to be picked up and inconsistent information ignored. Consequently, the belief that the schema is the right one to deal with the situation is confirmed and alternatives are less likely to be considered. At a conscious level, the individuals think they are considering the evidence in

an open-minded way, unaware that their attention is being directed selectively to certain aspects of the task.

A Pervasive Biasing Influence on Cognition

Problem-solving failures caused by the Einstellung effect are the downside of a normally efficient cognitive mechanism. To deal quickly with the familiar, we rely on the knowledge acquired through past experience. It seems inefficient to spend time looking for an alternative solution if we already have an adequate one. Indeed, in complex real-world situations people usually prefer to look for solutions that are good enough rather than trying for an elusive best that may be out of reach (Simon, 1990). Good solutions come from previous experience. But sometimes, as the Einstellung phenomena shows, this may be disadvantageous.

We believe that this mechanism may be at work in a range of biases in everyday thought. Once someone has a firmly entrenched idea about politics, the character of a colleague, or the best way to perform a task, it can be difficult to persuade them to think differently (Gardner, 2004; Rokeach, 1960). People seek evidence that will confirm a currently held view, not evidence that might disconfirm it (Wason, 1960; for a review, see Nickerson, 1998), and they will accept a lower standard for evidence that supports their view than they will for evidence that goes against it (Lord, Ross, & Lepper, 1979). The notoriously difficult insight problems (Duncker, 1945) present an extreme case of the inability to overcome previously activated schemas. People repeatedly tried to solve the problem with the same method although it had repeatedly proved unsuccessful. Even constant failure to find a solution is not enough to prevent people thinking of the same method when they face the same problem again (Knoblich, Ohlsson, & Raney, 2001).

Expertise does not prevent this bias. Doctors form opinions quickly based on previous experience, often missing important aspects that are inconsistent with their initial opinion (Groopman, 2007). Political experts and scientists are so heavily influenced by their favorite theories that they ignore valid negative evidence (Gould, 1996; Tetlock, 2005). Experts do not realize that their favored views seem so good because their attention has been directed to information that supports them and away from information that does not.

A similar mechanism may lie behind biases in other areas of cognition. The part-set cuing phenomenon in memory demonstrates the distracting effect of already-activated knowledge. For example, people who are asked to recall the names of American states and given a number of state names as examples recall fewer names than people who are not given the examples (Brown, 1968; see also Anderson, Bjork, & Bjork, 1994). The memories that have been activated by the experimenter impede access to other, unactivated areas of memory. The biasing of perceptual interpretation by prior knowledge is demonstrated when a well-learned schema overwrites perceptual input. For example, correct description of a playing card requires a much longer exposure if the color is reversed (a black three of hearts) than if it is normal. The effect can be surprisingly powerful. Even with exposures of a second, many cards are reported in their conventional rather than real coloring (a black three of hearts reported as a red three of hearts; Bruner & Postman, 1949).

In each case described above, already-activated knowledge biased the way people subsequently perceived and interacted with the world. This bias from schemas developed from previous experience is a blessing—without it we would have to deal with every situation as if we were encountering it for the first time. The mechanism that produces the Einstellung effect and many other biases in cognition shows that it can also be a curse. As John Maynard Keynes once said, ''The difficulty lies, not in the new ideas, but in escaping from the old ones, which ramify ... into every corner of our minds'' (1936/1973; p. xxiii).

Future Directions

The Einstellung effect resembles many biasing phenomena both in the laboratory and in everyday life. We hope that future work will establish if the mechanism we have shown to be behind one version of the Einstellung effect—the first activated thought biasing the subsequent allocation of attention and perceptual input—is also responsible for the other related phenomena. This ambitious goal may be approached with a mixture of behavioral and neuroimaging techniques. For example, the recordings of eye movements together with think-aloud protocols during Luchins's classic task might show why people are unable to solve the 1-solution problem. Similarly, the mixture of eye tracking and think-aloud protocols with the paradigms involving the perceptual judgments, confirmation bias, and reasoning may provide evidence on the mechanism behind these phenomena. Neuroimaging techniques have been applied to understanding the brain mechanisms behind phenomena of selective attention that show some similarities to the biases in thought and memory discussed here. Future neuroimaging studies of people experiencing Einstellung may show that the same control circuits that are involved in the selective biasing of thought and memory retrieval are involved in selective acquisition of sensory information.

Notes

1. Unlike Luchins's participants, all expert players found the solution once the familiar solution had been removed in the 1-solution problem. Nevertheless, the effect had a cost on the problem-solving process, as shown by another group of experts who solved the 1-solution problem immediately, without being exposed to the 2-soution problem. This group of experts, which was comparable in skill with the one that solved both problems, found the optimal solution in half the time (37 seconds) it took the group that had previously experienced the Einstellung effect (78 seconds). This result is at first sight paradoxical. The players who had previously been exposed to the 2-solution problem were more familiar with

the problem but nevertheless were slower to find the solution. The result is explained by a constant influence of the Einstellung effect, which continues to distract experts even when it is removed (see Bilalić et al., 2008a).

Recommended Readings

Bilalić, M., McLeod, P., & Gobet, F. (2008a). (See References). Demonstrates the mechanism behind the Einstellung effect.

Bilalić, M., McLeod, P., & Gobet, F. (2008b). (See References). Shows that the Einstellung effect can be demonstrated with experts, quantifies its strength, and offers theoretical explanations of the phenomenon.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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