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Why Good Thoughts Block Better Ones:

The Mechanism of the Pernicious Einstellung (set) Effect

Merim Bilalić

Oxford University

Peter McLeod

Oxford University

and

Fernand Gobet

Brunel University

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Correspondence address:

Merim Bilalić

Tübingen University

Department of Neuroradiology

Experimental MRI

Hoppe-Seyler-Str. 3

72076 Tübingen, Germany

Phone: +49 7071 2987 384

Fax: +49 7071 294 371

Email: merim.bilalic@med.uni-tuebingen.de

Abstract

The Einstellung (set) effect occurs when the first idea that comes to mind, triggered by familiar features of a problem, prevents a better solution being found. It has been shown to affect both people facing novel problems and experts within their field of expertise. We show that it works by influencing mechanisms that determine what information is attended to. Having found one solution, expert chess players reported that they were looking for a better one. But their eye movements showed that they continued to look at features of the problem related to the solution they had already thought of. The mechanism which allows the first schema activated by familiar aspects of a problem to control the subsequent direction of attention may contribute to a wide range of biases both in everyday and expert thought - from confirmation bias in hypothesis testing to the tendency of scientists to ignore results that do not fit their favoured theories.

Key words: Einstellung (set) effect, Fixation, Problem solving, Expertise, Eye movements, Chess, Confirmation bias, Thinking

Why Good Thoughts Block Better Ones: The Mechanism of the Pernicious Einstellung Effect

> The difficulty lies, not in the new ideas, but in escaping from the old ones, which ramify ... into every corner of our minds.
>
> *John Maynard Keynes (1936/1973; p. xxiii)*

The counter-intuitive possibility that prior knowledge can have a negative effect on future performance is a theme in a range of areas of psychology that at first sight might seem unrelated. For example, in negative transfer paradigms previous experience makes it more difficult to adapt to a new setting than it would be without such experience (Besnard & Cacitti, 2005; McCloy, Beaman, Morgan, & Speed, 2007; Schwartz, Bransford, & Sears, 2005; Singley & Anderson, 1989; Thorndike & Woodworth, 1901). Similarly, in the part-set cueing phenomenon people who are given a portion of previously studied/memorized material were in fact hampered by this 'help' when they tried to recall the remaining material compared to people who were just asked to recall the material (Roediger, 1973; Basden & Basden, 1995. Another example is offered by insight problems, first investigated by Köhler (1917/1925), Maier (1930, 1931) and Duncker (1945). Although there are different theories of why these problems are so hard to solve, most agree that the difficulty lies in the initial mental representation of the problem, determined by prior knowledge, from which people are unable to escape even though it does not lead to a successful solution (Kaplan & Simon, 1990; Kershaw & Ohlsson, 2004; Knoblich, Ohlsson, Haider, & Rhenius, 1999; MacGregor, Ormerod, & Chronicle, 2001; Ohlsson, 1992; Smith, 1995). A similar effect can be found in the motor system. Common actions become automated through frequent use and are triggered by familiar situations without conscious thought. This usually leads to efficient responses to the demands of everyday life. But when a specific context is strongly associated with a well-learnt, but now inappropriate, pattern, the familiar pattern can emerge with unintended results (Norman, 1981). These may be amusing (or embarrassing) if one dials a familiar telephone number at the wrong time (e.g., Woltz, Gardner, & Bell, 2000). But the result can be catastrophic if someone controlling a nuclear reactor executes a common but now inappropriate sequence (Reason, 1990). Finally, the way people seek information is biased by their prior knowledge. When people test a theory, they look for evidence that is consistent with what they already believe rather than objectively assessing any evidence even if it might disconfirm their previously held belief (Dawson, Gilovich, & Regan, 2002; McKenzie, 2006; Nickerson, 1997; Wason, 1960; Westen, Kilts, Blagov, Harenski, & Hamann, 2006).

An instance of the negative impact of previous knowledge is known as the Einstellung (set) effect. This occurs when the first idea that comes to mind, triggered by previous experience with similar situations, prevents alternatives being considered. If this initial idea is not the best way to solve the problem, the optimum solution may be missed. The effect was first demonstrated experimentally by Luchins (1942), who gave people a series of problems that could be solved by a fixed method which they quickly learnt. Then he gave them a problem that appeared similar to the previous ones but which could not be solved by the same method (the 'extinction' problem). Many said it was insoluble. The fixation of thought displayed by these people was demonstrated by a control group who were given only the extinction 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 (and now inappropriate) method to mind, preventing them from considering alternatives.

The Einstellung effect has been repeatedly demonstrated in the laboratory in a variety of forms using problems that do not require prior knowledge of the problem domain (e.g., Atwood & Polson, 1976; Chen & Mo, 2004; Delaney, Ericsson, & Knowles, 2004; Lippman, 1996;

Lovett & Anderson, 1996; McKelvie, 1990). These studies show that mental set can be induced by a small number of similar problems in people who have never experienced the task before. It can also be used to demonstrate the mechanisms behind the mistakes made by experts. Experts rarely make mistakes but when they do, it is usually because they think the situation is a familiar one and apply their usual, but now inappropriate, methods to find a solution (Singley & Anderson, 1989; Reason, 1990). For example, most errors that doctors make are not connected to their inadequate medical knowledge but rather to the tendency to form opinions quickly based on previous experience. Once the initial diagnosis is formed, it guides doctors in the search of supporting evidence which in turn brings dangers of missing important aspects unrelated to the initial diagnosis (Croskerry, 2003; Graber, Franklin, Gordon, 2005; Groopman, 2007; Kassirer & Kopelman, 1989). Such errors by experts with real life problems (where the errors are induced by knowledge of a well-learned procedure in long-term memory) resemble errors induced by Einstellung problems in the laboratory (where the mind set is induced by short-term memory of a newly learned procedure).

Despite the potential importance of the Einstellung effect for understanding why experts sometimes fail to find the optimum solution to a problem within their area of expertise, there are few studies investigating the effect with experts (for similar research on how experts can fail *outside* their domain, see Frensch & Sternberg, 1989; Hecht & Proffitt, 1995; and Wiley, 1998). One set of studies that has looked at this is Saariluoma's (1990; 1992) demonstration that skilful chess players can fall victim to the Einstellung effect. The players tried to solve a number of chess problems where a familiar motif led to the solution. They were then presented with a problem that had two solutions. One was the familiar solution they had used to solve the previous problem, but was sub-optimal; the other was less familiar but optimal. Most players failed to find the optimal solution in the presence of the familiar solution. Saariluoma concluded that chess players can suffer from the Einstellung effect.

Bilalić, McLeod, and Gobet (2008) extended Saariluoma's observations, confirming that expert chess players can experience the Einstellung effect, and showing that it can be quantified. They showed expert players (Candidate Masters, Masters, and International Masters[1]) a number of problems such as the one shown in Figure 1a, and asked them to find the shortest way for White to achieve checkmate. There were two solutions, one a well-known solution (smothered mate) taking five moves and the other (the optimal solution) a less familiar one taking three moves. The players who found the familiar solution but failed to find the optimal one were then shown a similar problem where the familiar solution had been disabled, leaving only the optimal one (shown in Figure 1b). All the experts found the shorter solution in the 1-solution problem, showing that they were capable of finding it when not distracted by the familiar one. To quantify the impact which the familiar solution had on the performance of expert players in the 2-solution problem, Bilalić et al. (2008) exploited one of the advantages of chess as a domain for studying problem solving – the presence of an interval scale for measurement of skill (see Footnote 1).

Similarly to the studies on transfer, Bilalić et al. (2008) used a control group of weaker players (Class A, Class B, and Class C) and showed them the 1-solution problem only. The Einstellung effect was quantified by seeing how much weaker a player had to be, when only the optimal solution was present, to show comparable performance to that of a better player when the distracting effect of the familiar solution was present (for similar measures of transfer see the first chapter of Singley & Anderson, 1989). The performance of the International Masters (5 SDs above average) on the 2-solution problem was comparable to that of the Class A players (2 SDs above average) on the 1-solution problem, the performance of the Masters (4 SDs above average) was comparable to that of the Class B players (1 SD above average) and the performance of the Candidate Masters (3SDs above average) was the same as the Class C players (average). 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 three standard deviations lower in skill. Similar results were obtained using different problems and the more naturalistic instruction to find the best move (Bilalić et al., 2008). Three standard deviations is a gulf in skill level. The chance of a player being beaten by one 600 Elo points lower is close to zero. And yet the Einstellung effect temporarily reduced the problem solving ability of the experts to that of the less skilled players. It is a very powerful effect.

Figure 1

Bilalić et al. (2008) also found that the Einstellung effect could not be demonstrated with Grand Masters (players more than five SDs above mean chess skill) with the problems shown in Figure 1 because they all found the optimal solution to the 2-solution problem. But Grandmasters did show the Einstellung effect in problems where the optimal solution was more difficult to find. Similarly, with problems where the less obvious solution was easier to find than in this one, the Einstellung effect could no longer be demonstrated with Candidate Masters because they all found the optimal solution to the 2-solution problem. But with these easier problems the effect could now be measured with weaker players (e.g., Class A) as the necessary control group of even weaker players (i.e., weaker than Class C) started to find the optimal solution in the 1-solution problem. Thus the demonstration of the Einstellung effect depends on an interaction between the skill of the individual and the difficulty of the less obvious solution. With harder problems it can be demonstrated with stronger players, with easier problems it can be demonstrated with weaker players. The ability to resist the Einstellung effect and find the optimal solution in any given problem is greater the more skilful the player. But the effect can still be shown, with a problem of appropriate difficulty, whatever the level of expertise of the individual player.

We show, by measuring players' eye movements, that the mechanism by which the first idea prevents a better idea coming to mind can be demonstrated. Crucially, we find that players believed that they were actively searching for better solutions when in fact they continued to look at aspects of the problem related to the first idea they considered. This is why the Einstellung effect is pernicious – people do not realize that it is influencing their thoughts.

Experiment 1

Why did many of the players fail to find the optimal solution to the 2-solution problem (Figure 1a) in Bilalić et al. (2008)? Is it possible that the players were so blinded by the familiar solution that they did not notice at all the critical features necessary to find the better one? Or is it plausible that they noticed the critical features but could not connect them with the optimal solution? In the previous experiments we used verbal protocols to glean insights into the mechanisms involved in the Einstellung effect. These showed that all players, even after they had spotted the familiar solution, looked further for a better one. Unfortunately, the verbal protocols did not provide a lot of information about what aspects of the position players attended to when looking for a better solution. The problem used in this study was similar to problems used in insight studies in that the finding of the optimal solution occurs suddenly. The players did not verbalize much just before the insight either because they did not look very hard due to the satisfactory nature of the first solution, or they did not have any indication that they were close to a better solution. It has been shown that people cannot adequately report how close they are to solving insight problems (Metcalfe, 1987; Metcalfe & Wiebe, 1987). It has also been argued that verbal protocols may not be helpful when trying to understand the cognitive processes engaged in solving insight problems (Schooler, Ohlsson, & Brooks, 1993). Another limitation of the use of verbal protocols in this context is that chess is visuo-spatial in character and it may not always be possible to recode visuo-spatial information into verbal statements (de Groot & Gobet, 1996).

A possible solution is to measure the players' eye movements. Unlike verbal protocols, eye fixations unambiguously provide information about which features of the display are attended (Rayner, 1998). The direction of gaze shows which features of the problem have been attended to, and the amount of time spent fixated is related to the amount of time spent processing them (Findlay & Gilchrist, 1998; Just & Carpenter, 1976). The technique of measuring eye movements has provided useful information when applied to general problems (Epelboim & Suppes, 2001; Hodgson, Bajwa, Owen, & Kennard, 2000; Van Gog, Paas, & Van Merrienboer, 2005) as well as to insight (Grant & Spivey, 2003; Jones, 2003; Knoblich, Ohlsson, & Raney, 2001) and chess problems (Charness, Reingold, Pomplun, & Stampe, 2001; de Groot & Gobet, 1996; Reingold, Charness, Pomplun, & Stampe, 2001; Reingold, Charness, Schultetus, & Stampe, 2001; Tikhomirov & Poznyanskaya, 1966).

On the basis of the results in Bilalić et al.'s (2008) Experiment 1 we assumed that players of Candidate Master level would fail to find the optimal solution in the 2-solution problem but that they would find it in the 1-solution problem. This would enable us to compare the eye movements of players failing to find the optimal solution to the 2-solution problem (who experienced the Einstellung effect) with the eye movements of players succeeding in finding it in the 1-solution problem (who did not).

Method

Participants. Two groups of Candidate Masters, all male, participated in the experiment (see Table 1 for details). The experts had not participated in previous experiments on the Einstellung effect and were recruited from local chess clubs in Oxford and Witney (England). They were offered £15 or a copy of a chess program for their participation in the experiment.

Table 1

Stimuli. The two problems shown in Figure 1 were used. The first problem, Figure 1a, has two solutions. One is smothered mate, a familiar sequence to any skilled player. This is an elegant and easily remembered motif, taught to all young chess players, where the strongest piece, the queen, is sacrificed in order to draw one of the opponent's pieces onto a square that blocks the escape square for the king. This sequence solves the problem by producing checkmate in five moves. There is also a shorter but less familiar solution that solves the problem by delivering checkmate in three moves. In the second problem (Figure 1b) only the shorter solution is possible. The smothered mate has been disabled by changing just one element in the problem (moving Black's white-squared bishop from c6 to h5). Otherwise the problems are the same.

Design, procedure, and apparatus. The first group was presented with the 1-solution problem only. The second group was first shown the 2-solution problem and then the 1-solution problem if they failed to find the shortest solution to the 2-solution problem. Both groups were told that they should look for the shortest way to win and that they would have unlimited time to find the solution. The instruction was to "find the shortest way to win" rather than the more ambiguous "find the best move" as it is difficult to argue that the shorter solution is 'better' than the smothered mate solution. Any player in the second group who failed to find the shorter solution was then shown the 1-solution problem (Figure 1b) with the same instructions. As in normal tournament play, the players were not allowed to move the pieces.

The problems were shown using images (400 x 400 pixels) created with ChessBase 8, standard chess software that produces images familiar to most players. The squares on the image measured 4.9 x 4.6 cm. The problems were presented on a plasma screen 70 cm from the players. The players' eye movements were recorded by an iView 3 RED II infra-red remote eye-tracking device from SensoMotoric Instruments, sampling at 50 Hz. The system had an error of 0.5 – 1^{o}, corresponding to 0.6 to 1.2 cm on the board. We used a nine-point calibration with bi-quadratic functions before each problem.

The players watched the board with their head on a chin rest. A practice problem (a middle game position) was presented first to make participants familiar with the procedure of calibration. Players were required to look at a fixation cross in the centre of the screen to establish a similar starting point for all players. They were instructed to announce their solution only when they were certain of it. They did not talk during problem solving as head movement associated with talking reduces the accuracy of the eye movement recording. After announcing the solution, retrospective verbal protocols were collected from the players (de Groot & Gobet, 1996; Ericsson & Simon, 1993). The sessions lasted for about 20 minutes.

Eye movement analysis. The analysis will focus on the time spent fixating the crucial squares for at least 100 ms. To combine eye movement data across subjects who took different lengths of time to solve the problem, the problem solving process was divided into six intervals (see Knoblich, Ohlsson, & Raney, 2001, for a similar procedure of analysing eye movement data). The first interval was the first ten seconds when players were getting familiar with the position. The last interval was the last five seconds before players found the optimal solution (1-solution problem) or before they proposed the suboptimal solution (in the 2-solution problem). The remaining problem-solving period was divided into four intervals of equal duration.

Eight expert chess players who did not participate in the study (*M* Elo 2294 ± 192; *M* age = 27 ± 4; two female) were asked to indicate the importance of a number of squares for the smothered mate and optimal solutions. They estimated the importance using a 7 point likert scale (three points on the scale were labelled: 1 = unimportant, 4 = moderately important, 7 = very important). The estimates of the relative importance of the squares are shown in Table 2. On the basis of these estimates we chose the squares b2, h6, h7, and g7 (marked by circles in Figure 1a) as critical for the optimal solution but not the smothered mate, and the squares f7, g5, and g8 (marked by squares) as critical for the smothered mate solution but not the optimal solution. The percentage of the time spent on these squares was taken as the dependent variable.

Table 2

Results and discussion

The group who were only shown the 1-solution problem all found the optimal solution, needing on average 79 s (*SD* = 25) to do so. The group who were shown the 2-solution problem all said, like the players of comparable skill in Bilalić et al. (2008) Experiment 1, that the smothered mate was the shortest solution, taking on average 37 seconds (*SD* = 20) to reach this decision. All players facing the 2-solution problem reported that after they had found the smothered mate they looked for a shorter mate but failed to find one. They nevertheless found the optimal solution when shown the 1-solution problem (*Mean* = 148 s, *SD* = 90), showing that they were experiencing the Einstellung effect when they failed to find the shorter solution to the 2-solution problem.

To investigate the mechanism of the Einstellung effect we compared the eye movements of players who were experiencing the Einstellung effect (Group 2 looking at the 2-solution problem) with those who were not (Group 1 looking at the 1-solution problem). Figure 2 shows the percentage of time that the two groups spent looking at the two sets of squares identified as more important for one solution or the other, or at the control set of squares. Initially, the group looking at the 2-solution problem (Figure 2a) spent more time looking at the squares relevant to the smothered mate (the open circles). Having found that solution, they said in their retrospective protocols that they were looking for a shorter one. But, in fact, they continued to look at squares relevant to the familiar smothered mate solution throughout the time they spent on the problem (the interaction between the % of time looking at the two sets of squares and the six time periods was not significant - F (5, 20) = 0.6, *ns*). In contrast, the group looking at the 1-

solution problem (Figure 2b) spent gradually more time looking at the squares relevant to the optimal solution (the filled triangles) that they eventually found (the interaction between the % of time looking at the two sets of squares and the six time periods was significant - F (5, 20) = 11.9, $p < .001$, $\eta_p^2 = .75$). Although the group looking at the 2-solution problem (Figure 2a) all stated that they were actively looking for alternatives after spotting the smothered mate, and presumably believed they were doing so, they spent much of their time continuing to look at the squares that were crucial to the smothered mate. Presumably, the new ideas they considered were related to the familiar solution. The players did spend some time looking at the squares that were involved in the optimal solution, but failed to realise their significance.[2]

Figure 2

Figure 3 shows that when group 2, who had failed to find the optimal solution in the 2-solution problem, were given the 1-solution problem, they exhibited a similar pattern of eye movements to the players in group 1 who were solving the 1-solution problem only (the interaction between % of time looking at the two sets of squares and time is significant – F (5, 20) = 5.4, $p < .001$, $\eta_p^2 = .57$). The players were looking more at the squares important for the optimal solution and less at the squares important for the smothered mate in the last five seconds before announcing the solution than they did it the previous stages of the problem solving process.

Figure 3

Experiment 2

Although they showed that the effect is very powerful, Bilalić et al. (2008) did not fully replicate Luchins' original results (1942) where many participants could not find the solution to the 1-solution problem. It is not surprising that expert chess players, three and more standard deviations above the skill level of average players, were able to find a three-move mate when the distracting effect of the familiar solution was removed. The question remains, however, whether the players were affected by the Einstellung effect while they searched for the solution in the 1-solution problem. It is possible, for example, that they experienced more difficulty solving the 1-solution problem after they had first tried to solve the 2-solution problem. The Einstellung effect induced by the 2-solution problem may not have prevented them from finding the optimal solution in the 1-solution problem, as was the case with Luchins' participants in the extinction problem, but it might have slowed them down. This possibility is suggested by the result of Experiment 1. The players in Group 2 who had already seen the 2-solution problem took longer (148 s) to find the solution of the 1-solution problem than those in Group 1 (79 s) who had not seen the 2-solution problem, although the difference failed to reach the conventional level of significance ($t(8) = 1.67$, $p = .13$, $d = 1.2$). In Experiment 2 we investigate whether previous experience of the 2-solution problem slows solution of the 1-solution problem across a range of skill levels.

Method

Participants. We recruited three groups of expert chess players, International Masters, Masters and Candidate Masters in England (all male), who had not participated in previous experiments on the Einstellung effect (see Table 2 for details). Participation was voluntary and without reward.

Table 2

Stimulus. This was the 1-solution problem used in Experiment 1 shown in Figure 1b.

Design. The players were shown only the 1-solution problem, hence they were not experiencing the Einstellung effect. We compared their performance to that of the participants of comparable skill level in Bilalić et al.'s (2008) Experiment 1 who saw the 1-solution problem after failing to find the optimal solution in the 2-solution problem (Figure 1a) and so were experiencing the Einstellung effect. The details of this sub-group from Bilalić et al. (2008) are shown in Table 3.

Table 3

Procedure. The problem was shown on the 15" screen of a laptop computer using images created with ChessBase 8. Players were told that they should look for the shortest way to win and that they would have unlimited time to find the solution. As in normal tournament play, the players were not allowed to move the pieces. They were asked to think aloud as they tried to solve the problem. A general practice problem (multiplying two 2-digit numbers) and a chess specific practice problem (a middle game position) were used to get players familiar with the think-aloud method (see Ericsson & Simon, 1993). All players' statements were tape-recorded and the solution times were derived from the verbal protocols. The moment when players announced that they had found a solution was deemed to be the solution time. The time needed to spell out the sequence was not counted in the solution time. All players were tested individually. Each session lasted between 10 to 20 minutes.

Results and discussion

All players found the optimal solution to the 1-solution problem. Figure 4 shows that at each skill level the players in this experiment found the solution in roughly half the time taken by the players in the first experiment of Bilalić et al. (2008) who had already seen the problem with the familiar solution and so were experiencing Einstellung ($t(44) = 2.16$, $p = .036$, $d = .65$). (The interaction between skill and group was not significant (F (2, 40) = 0.9, $p > .40$, $\eta_p^2 = .04$.)

Figure 4

Without the idea of the continuing influence of Einstellung this result would be paradoxical. The players in the first experiment were more familiar with the position but were slower to find the solution. The Einstellung effect does not stop as soon as the stimulus that brought it about is removed. Like a decaying priming effect, it continued to distract the players.

General Discussion

In previous research (Bilalić et al., 2008), we showed that the Einstellung effect, the blocking of new ideas by the first one that comes to mind, reduced the problem solving ability of chess experts to that of players about three standard deviations below them in skill. In the present paper we show that the origin of the effect was that players continued to look at the squares related to the first idea they had, even though they reported that they were looking for alternative solutions.

The eye movement data suggest a mechanism by which one pattern of thought can prevent others coming to mind. As soon as a problem or situation is recognized as familiar, the schema for dealing with it is activated. The perceptual mechanisms that lead to recognition and the creation of chess experts' schemata have been spelled out in detail in template theory (Gobet & Simon, 1996, 2000) and have been implemented in a computational model (de Groot & Gobet, 1996; Gobet & Simon, 2000; Gobet et al., 2001). The schema directs attention towards those aspects that are relevant to itself and away from those that are not. This is reflected in our study by more time spent on the squares crucial for the familiar solutions than on the squares crucial to the optimum solution or on control squares. Again, template theory details mechanisms by which what is called the 'hypothesis' in the theory - the largest perceptual chunk or schema identified so far - directs attention so as to gather more information compatible with itself (de Groot & Gobet, 1996, p. 233-234). As John Maynard Keynes claimed in the opening quote, our previous experience starts a self-fulfilling circle which begins with information consistent with the already activated schema being more likely to be picked up. 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 (Keren, 1984). People think they are considering the evidence in an open-minded way, not realising that their attention is being selectively directed to only certain aspects of the problem. Those things that they notice do indeed fit in with the activated schema and so confirm the view that the way they are dealing with the situation is the correct one. Things that do not fit in are either not noticed, or if they are, as was the case in this study, not integrated because they do not fit the activated schema.

It is important to notice that the players looking at the 2-solution problem did spend some time on the squares relevant to the optimal solution. It is not that they were completely blinded by the familiar solution and did not notice other critical features. The critical features associated with the 'optimal' squares appear to have been suppressed by the activation of the familiar solution because the players spent more time on these squares once the familiar solution had been removed (i.e. in the 1-solution problem). It is possible that because of this inhibition from the familiar solution the players spent too little time examining the crucial features of the problem to make use of that information. The behaviour of the chess players resembles the part-set cuing phenomenon where the presentation of the cued items impairs the recall of non-cued items (Anderson, Bjork, & Bjork, 1994). (For the application of the paradigm in chess see Drinkwater, Dagnall, & Parker, 2006; Watkins, Schwartz, & Lane, 1984).

Cognitive mechanisms that prevent us spending time looking for an alternative solution to a problem when we already have an adequate one are obviously useful. Simon (1956, 1990) showed that in complex real world situations people usually prefer to look for solutions that are good enough rather than spending their energy looking for an elusive best that may be out of reach. Other researchers (Baron, 1994; Friedrich, 1993; Kanouse, 1972; Schwartz, 1982) have expressed a similar pragmatic view that people lean towards producing desirable outcomes instead of determining the truth. The Einstellung effect shows the downside of this time saving mechanism when it prevents us finding a better solution. The mechanism of the Einstellung effect identified here may be similar to the mechanisms behind negative transfer, confirmation bias, and capture or ‘automated action’ errors. They all feature the same theme – familiar aspects of the problem activate a schema which in turn controls the behavioural response, in this instance, the allocation of attention.

It is possible that a similar mechanism lies behind a range of well-known biases in everyday thought. For example, people accept a lower standard of evidence when accepting evidence that supports the view they already hold than they do for evidence that goes against it (Lord, Ross, & Lepper, 1979; MacCoun, 1998). Once someone has a formed a strong opinion 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. New evidence is ignored and the old point of view retained unchanged by the new information (Gardner, 2004; Rokeach, 1960). Just how far this fixation can go is demonstrated in insight problems. People repeatedly try to solve the problem with the same method even though it has proved unsuccessful (Bowden & Jung-Beeman, 1998; Grant & Spivey, 2003; Knoblich, Ohlsson, & Raney, 2001; Smith, 1995; see also Defeyter & German, 2003). Constant failure to find a solution is not enough to change the schema they use.

The insidious mechanism behind the Einstellung effect operates both in people newly introduced to a problem, as with Luchins’ participants and, as we showed here, with people operating in a domain with which they have years of experience. It may prevent scientists assessing their data objectively. Expert political scientists do not change their theories when events prove their predictions wrong; they keep the theory and discount the evidence (Tetlock, 2005). In a survey of distorted scientific analyses of data on the measurement of human intelligence, Gould (1996) concluded: “In most cases … we can be fairly certain that biases … were unknowingly influential and that scientists believed they were pursuing unsullied truth”

(p. 59). Just like people facing an Einstellung problem in the laboratory, scientists may not realize that their favoured theory seems so good because their attention has been directed to information that supports it and away from information that does not.

The mechanism behind the Einstellung effect and similar phenomena is a universal characteristic of the human mind – it affects both ordinary people and the most knowledgeable experts. A perfect description of the distortion of human thought it produces was given by Francis Bacon nearly 400 years ago in the *Novum Organum*:

> The human understanding when it has once adopted an opinion ... draws all things else to support and agree with it. And though there be a greater number and weight of instances to be found on the other side, yet these it either neglects or despises, or else by some distinction sets aside and rejects; in order that by this great and pernicious predetermination the authority of its former conclusion may remain inviolate. ... Men mark the events where they are fulfilled, but where they fail, though this happen much oftener, neglect and pass them by. But with far more subtlety does this mischief insinuate itself into philosophy and the sciences, in which the first conclusion colours and brings into conformity with itself all that comes after ... It is the peculiar and particular error of the human intellect to be more moved and excited by affirmatives than negatives (p. 36).

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Footnotes

[1] Chess skill is measured with the Elo rating, an interval scale with a theoretical mean of 1500 and a theoretical standard deviation of 200 (Elo, 1978). Average players with the rating between 1400 and 1600 are called Class C players, 1600-1800 Class B (+1SD above the mean), 1800-2000 Class A (+2SD), 2000-2200 are called Candidate Masters (+3SD), 2200-2400 Masters (+4SD), 2400-2500 International Masters (around 5SD above the mean), and finally, players above 2500 are called Grand Masters.

[2] In the later stages of the problem players spent more time on squares related to the optimal solution than on a random set of non-critical occupied squares – (the analyses available from the authors). Thus it seems that the players did become more receptive to the optimal solution with time but not sufficiently to prevent them from choosing the familiar solution. We are grateful to Neil Charness for suggesting the use of a control set of random squares to test the significance of the increase in time spent on the optimal squares apparent in Figure 2a.

Table 1. The classification, mean Elo rating, mean age, and numbers of participants in Experiment 1.

Classification	*Mean Elo ± SD*	*SDs above mean*	*Mean age ± SD*	*n*
1-solution				
Candidate Master	2066 ± 28	3	32 ± 14	5
2-solution				
Candidate Master	2113 ± 54	3	39 ± 10	5
Total	*2090 ± 48*		35 ± 12	*10*

Table 2. Importance estimates on a 7 point likert scale (1 = unimportant; 7 = very important) of the squares for the smothered and optimal solution in the 2-solution problem, by a new group of experts who did not participate in the study. * indicates those squares where the difference in importance between the two solutions is significant at $p < .05$.

	Solution			
	Smothered mate		Optimal	
Square	M	(SD)	M	(SD)
b2*	1	(0)	5.3	(2)
h6*	4.8	(1.4)	6.9	(.4)
h7*	3.2	(1.4)	6.4	(.7)
g7*	3.1	(1.8)	6	(1.4)
f7*	6.6	(.7)	2.6	(1.7)
g5*	6.2	(1.2)	4.9	(1.6)
g8*	6.4	(.7)	3.9	(1.8)
e6	6.4	(.9)	6	(1.2)
f8	4.6	(2.1)	3.6	(2)
h8	4.8	(.8)	4.5	(.6)
g6	2	(1.4)	1.9	(1.4)
f6	1.9	(1.6)	2.4	(1.7)

Table 3. The classification, mean Elo rating, mean age, and numbers of participants in Experiment 2. Group 1 saw only the 1-solution problem. Group 2 had already seen the 2-solution problem but failed to find the optimum solution. (The Group 2 data are from Bilalić, McLeod, & Gobet, 2008)

Classification	*Mean Elo ± SD*	*SDs above mean*	*Mean age ± SD*	*n*
Group 1 (1-solution problem only)				
International Master	2406 ± 56	5	28 ± 6	3
Master	2287 ± 54	4	34 ± 8	9
Candidate Master	2132 ± 58	3	32 ± 8	11
Total	*2229 ± 115*		*32 ± 10*	*23*
Group 2 (2-solution problem, then 1-solution problem)				
International Master	2449 ± 26	5	37 ± 12	3
Master	2316 ± 60	4	39 ± 14	9
Candidate Master	2129 ± 45	3	27 ± 14	11
Total	*2224 ± 129*		*33 ± 14*	*23*

Figure legends

Figure 1. **a** 2-solution problem; **b** 1-solution problem. (These positions are based on an idea of Pertti Saariluoma.) White to move in both problems. In **a** the familiar smothered mate solution is possible: *1*. Qe6+ Kh8 *2*. Nf7+ Kg8 *3*. Nh6++ Kh8 *4*. Qg8+ Rxg8 *5*. Nf7#. The shorter optimal solution is: *1*. Qe6+ Kh8 *2*. Qh6 Rd7 *3*. Qxh7#, or *2*.… Kg8 *3*. Qxg7#. In **b** the smothered mate is no longer possible because Black's bishop now covers f7. The optimal solution is still possible. *1*. Qe6+ Kh8 (If *1*..... Kf8 *2* Nxh7#) *2*. Qh6 Rd7 *3*. Qxh7#, or *2*.… Kg8 *3*. Qxg7#, or *2* … Bg6 *3*. Qxg7#. The crucial squares for the familiar solution are marked by rectangles (f7, g8 & g5) and the optimal solution by circles (b2, h6, h7 & g7) in Figure 1**a.**

Figure 2. Average percentage of time (±SE of mean) spent looking at squares crucial to the familiar (Smothered Mate) solution and Optimal solution (f7, g5 & g8 and b2, h6, h7 & g7, respectively) as a function of time, for (**a**) players looking at the 2-solution problem and (**b**) players looking at the 1-solution problem. (The two sets of squares are just a subset of the 64 squares on the chess board and the percentage spent on these three sets of squares is unlikely to reach 100%.)

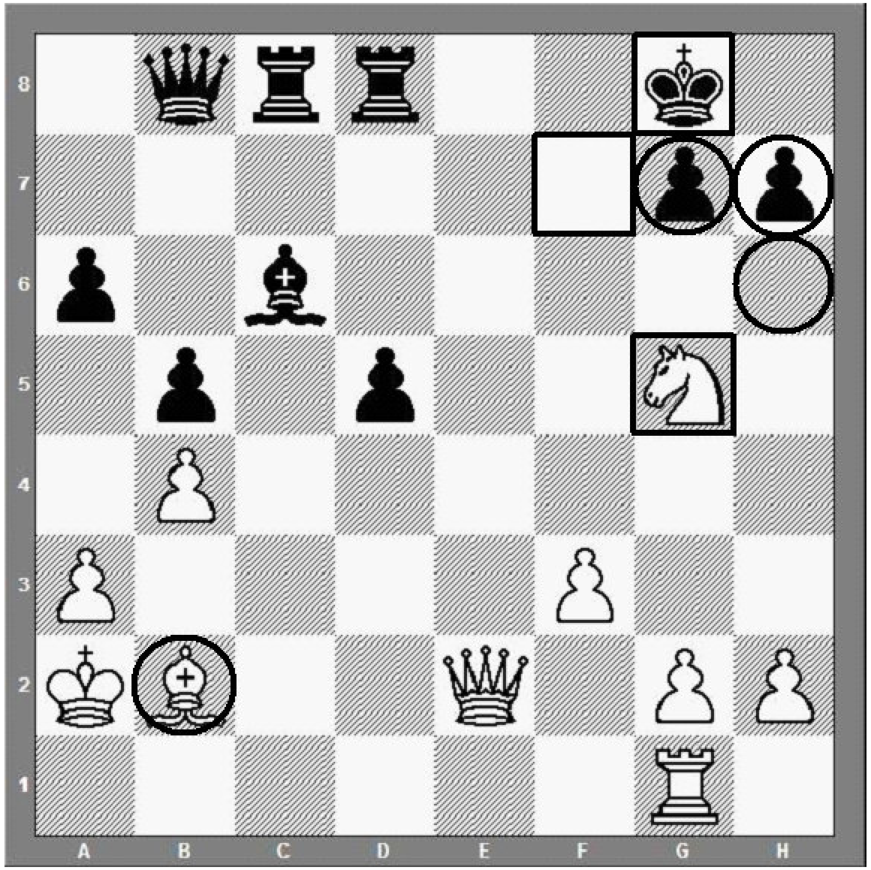
Figure 3. Average percentage of time (±SE of mean) spent on familiar Smothered Mate solution squares and Optimal solution squares in the 1-solution problem as a function of time for players who had previously seen the 2-solution problem. (The two sets of squares are just a subset of the 64 squares on the chess board and the percentage spent on these two set of squares is unlikely to reach 100%.)

Figure 4. The average time in seconds (±SE of mean) taken to find the optimal solution in the 1-solution problem by Candidate Masters (CM), Masters (M) and International Masters (IM) who had already failed to find it in the 2-solution problem (Group with Einstellung, n = 23) or who had not seen the 2-solution problem (Group without Einstellung, n = 23).

Bilalić, M., McLeod, P., & Gobet, F. (in press). Why good thoughts block better ones: The mechanism of the pernicious Einstellung (set) effect. *Cognition*.

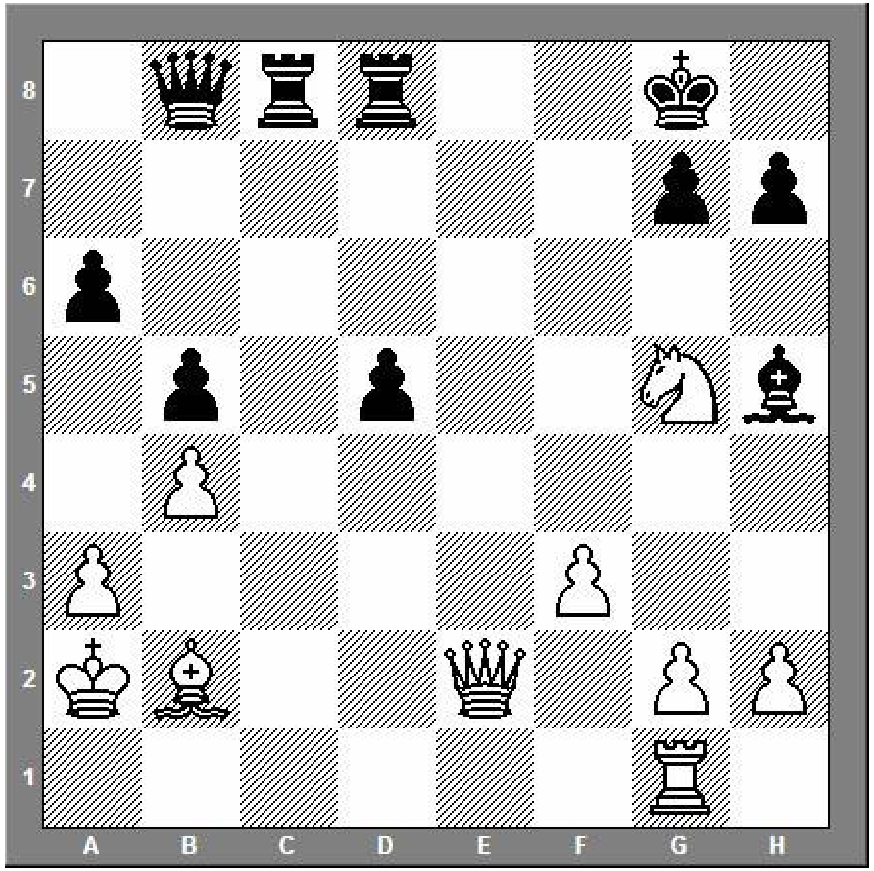
Figure 1

a



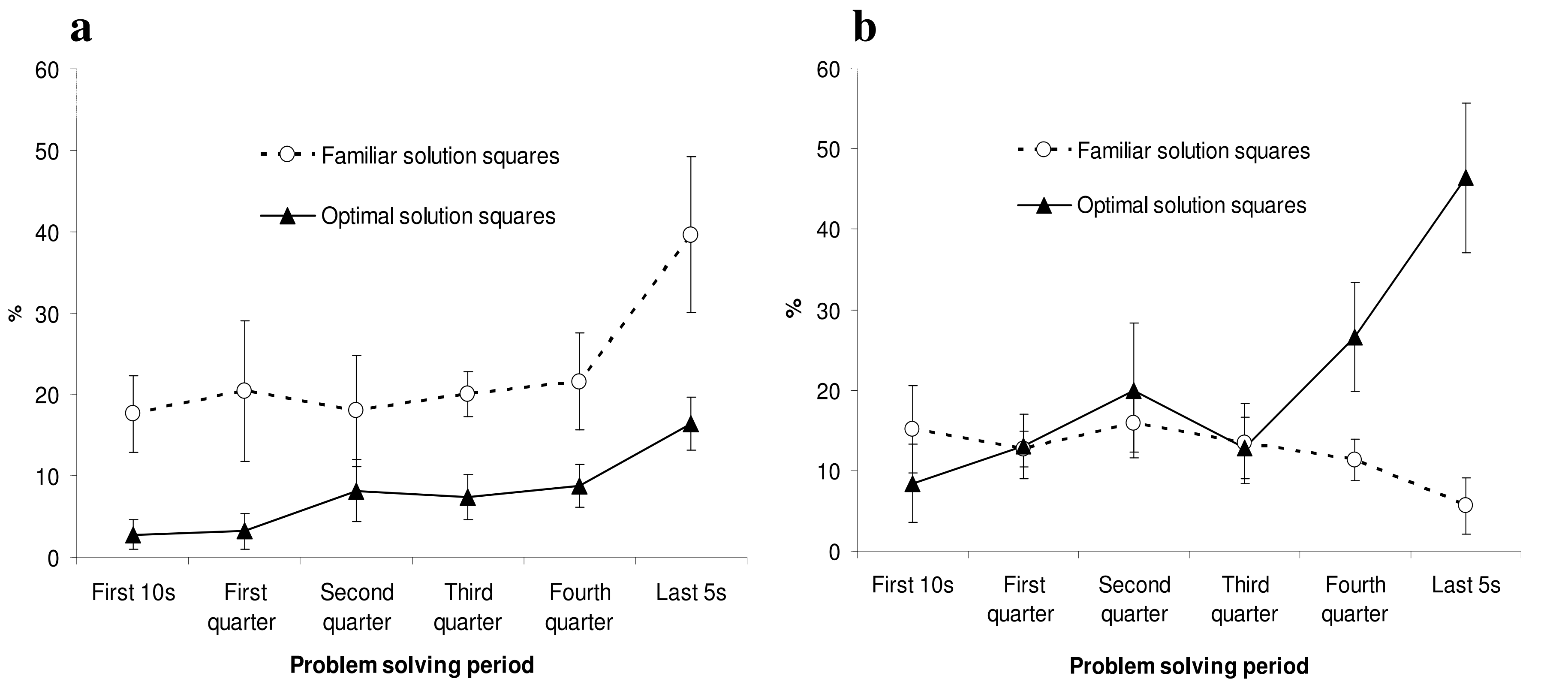
2-solution problem

b



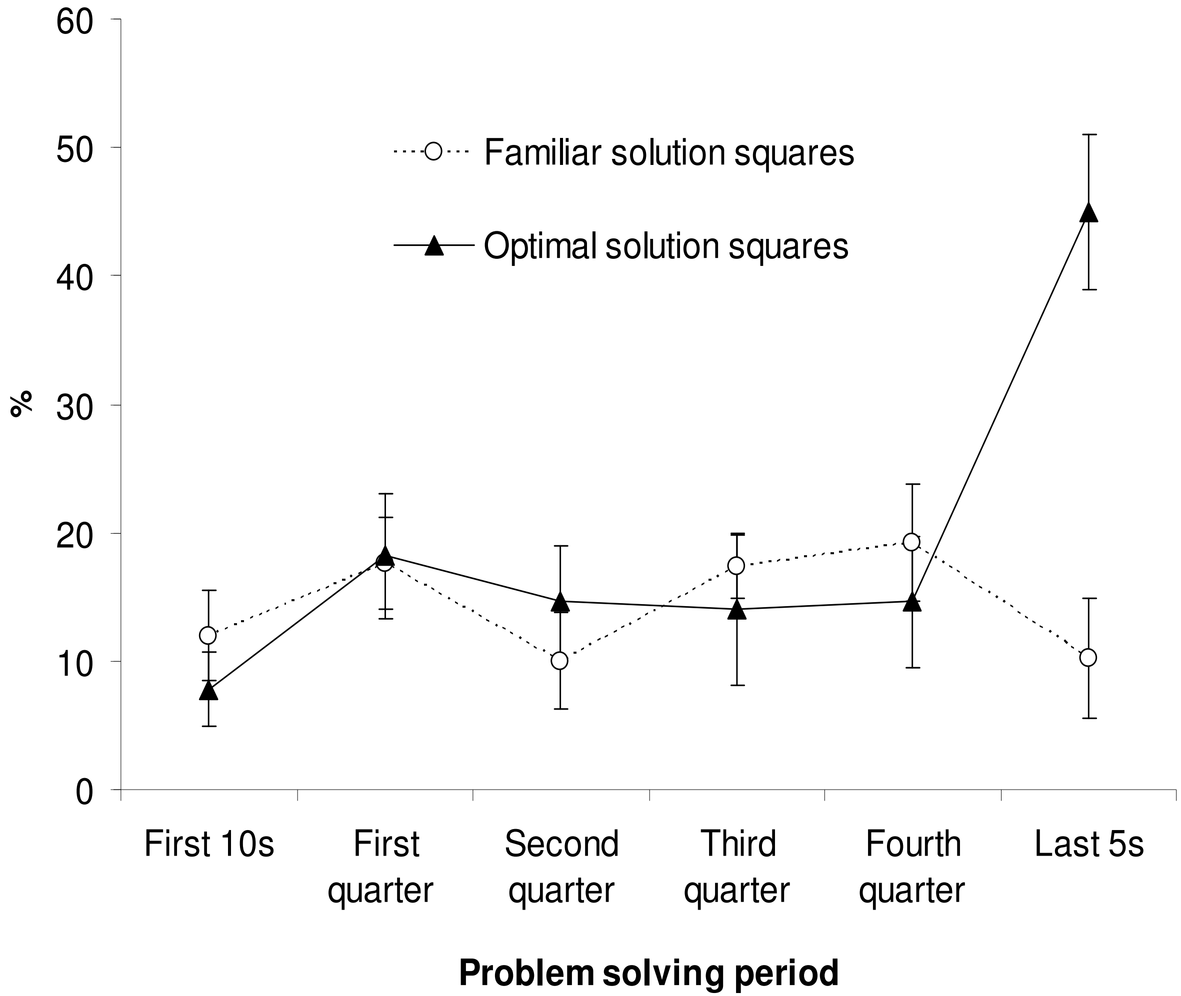
1-solution problem

Figure 2



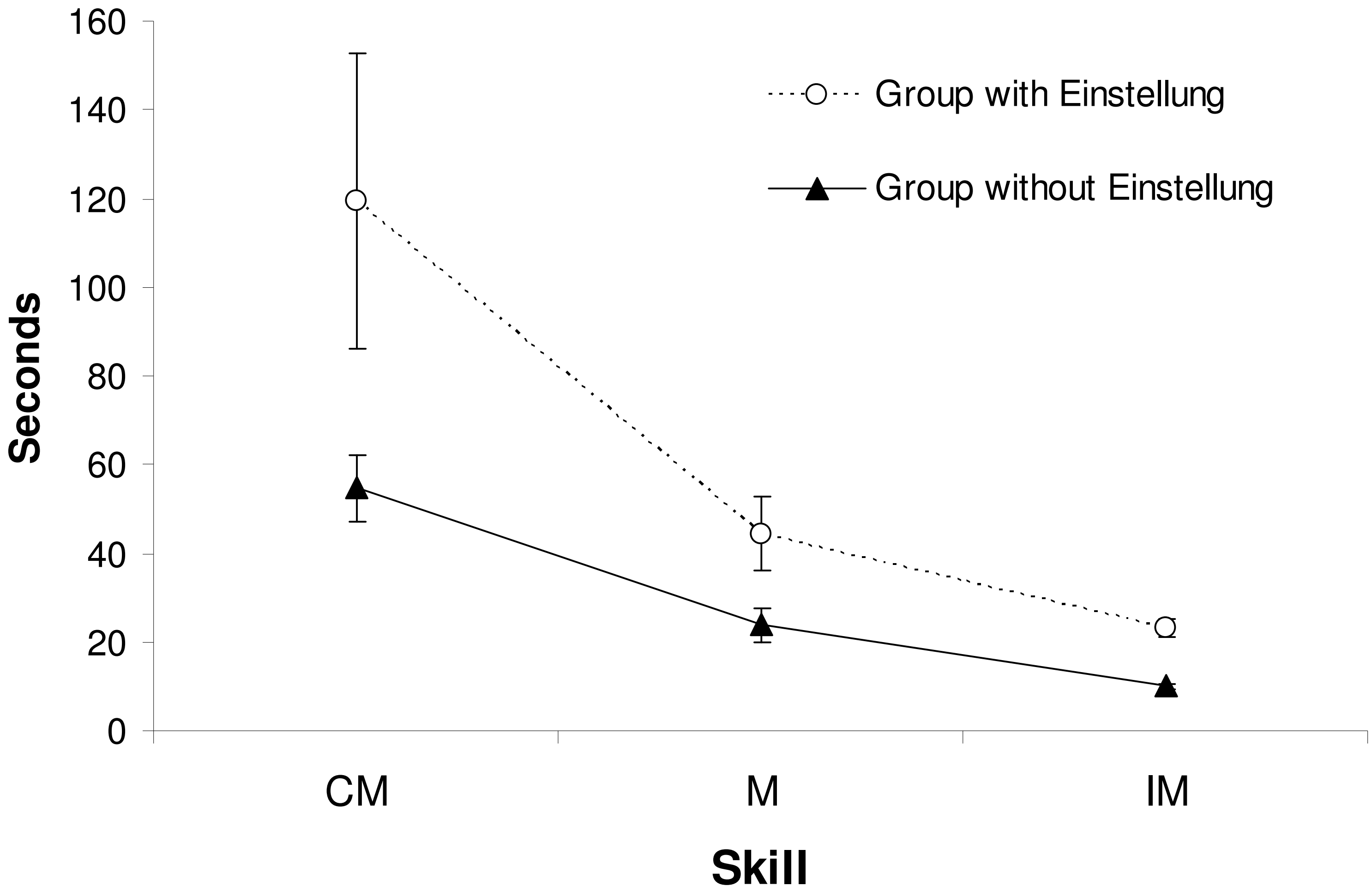
2-solution problem **1-solution problem**

Figure 3



1-solution problem

Figure 4


160
140
120
100
80
60
40
20
0
Seconds
Group with Einstellung
Group without Einstellung
CM
M
IM
Skill