# Implicit Learning Across Isoproblems in the Tower of London Puzzle is Impaired in Patients with Parkinson's Disease

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**Abstract.** Shallice's Tower of London is popular for assessing problem-solving. One feature of the Tower of London puzzle is the existence of a special class of problems: isomorphic problems, as yet little studied, require identical moves, but the colors of the balls are permuted. Thus, difficulty is the same even if the problems look different. Prior work suggests that implicit learning occurs when a series of isomorphic problems is solved ("iso-effect"). In a computerized version of the task, problem-solving performance by 9 patients with idiopathic Parkinson's disease was compared to healthy controls with regard to several measures of performance, including planning and execution time, moves, efficiency and errors. In general, patients needed more time and more moves to solve the problems, and their solutions were less efficient. Although both groups dedicated the same amount of their time to planning, controls found better solutions. Furthermore, controls showed learning across a set of five isomorphic problems (less time, fewer moves, increasingly efficient solutions), an effect demonstrably different from general learning. In contrast, patients did not improve their isomorphic problem performance. We thus confirmed an iso-effect in healthy participants and suggest that it may be related to implicit memory which is thought to be affected by Parkinson's disease.

Problem-solving research in Germany has largely moved away from static problems to dynamic problems. Joachim Funke was the key player who defined



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and explored the new research field of complex problem-solving. As early as 1983 (now 40 years ago!), he investigated the relationship between intelligence and performance in the complex problem-solving scenario "Tailorshop" for which he had re-written the code in the programming language BASIC to run on a Commodore computer (Funke, 1983). His proposal to describe complex problems either as linear structural equations or finite state automata has been very influential (Funke, 2001) and triggered a wealth of empirical studies. Today, the field of complex problem-solving is very prolific, full of interesting findings, novel approaches and discussions (Dörner & Funke, 2017).

Yet while dynamic, complex problems are closer to "real-world" problem solving, some static problems have become very popular testing tools. Classical examples are tower-transformation tasks such as the Tower of Hanoi (ToH) and the Tower of London (ToL), which are still widely used today. Their characteristics as well-defined problems with clear start and goal states and operators make them a valuable tool for neuropsychological testing and diagnosis (e.g., Carlin et al., 2000; Goel & Grafman, 1995; for a review, see Sullivan et al., 2009). They are also used to distinguish different problem-solving strategies such as hill-climbing or means-end-analysis (Dunbar, 1998). This area of research has seen important methodological advancements, too. First, improved formulations of their mathematical structure and the corresponding "state graphs", i.e., graphical representations of the entire problem space (Hinz et al., 2005). Second, the development of computerized versions of tower problems which enable the collection of a large number of variables of interest (e.g., solution times, number of moves, errors, efficiency). In particular, some software tools now include the possibility to map each move onto the state graph which allows a fine-grained analysis of problem solvers' trajectories through the problem space (Hinz et al., 2009; Kaller et al., 2011).

The present study implements the ToL which was originally designed by Tim Shallice (1982). To solve the ToL, problem solvers have to rearrange three differently colored balls that are placed on three rods from an initial configuration to match a certain goal configuration. There are two restrictions: only one ball at a time can be moved and only three, two, or one ball(s) can be placed on each of the three rods of descending lengths, respectively (see Fig. 1).

An interesting feature of the ToL is the existence of isomorphic problems ("isoproblems" for short), first recognized by Berg and Byrd (2002) and already discussed by Unterrainer et al. (2005). Isoproblems require identical moves, as they have the same start and goal position, but the colors of the balls are permuted. Past research indicates that problem solvers are not aware of their similarity (Johns, 2005). The present work focuses on this special sort of problem by exploring a peculiar learning effect that was found in a previous study (Faber et al., 2009). The so-called "iso-effect" describes an improvement in performance from one isoproblem to the next. In the Faber et al. study, 81 healthy volunteers were presented with a series of 22 problems in fixed order, with six isoproblems interspersed. Participants' performance improved significantly with respect to all variables investigated (solution time, initiation time, completion time, moves, and efficiency),

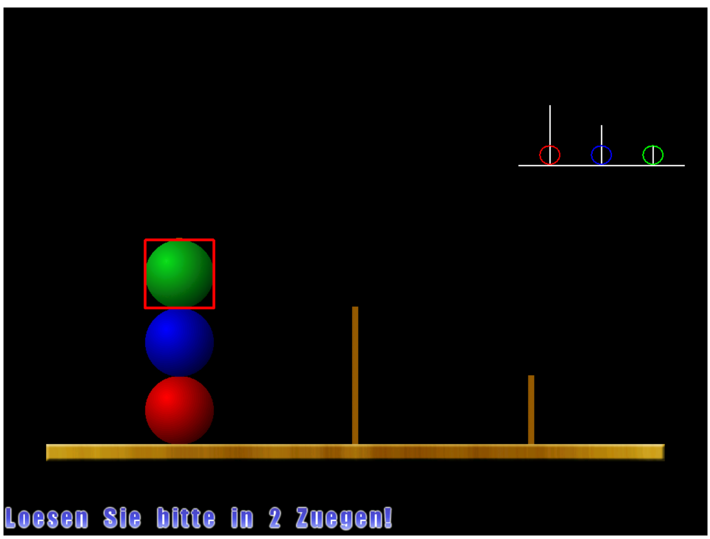


**Figure 1.** *Screenshot of the computerized Tower of London version used in this study. The goal state is depicted in the upper right corner.*

but only one third of the sample was aware of the repetition of these problems. From a comparison with other, non-isomorphic problems, it was concluded that the effect seems to be specific to isoproblems and distinct from general learning.

Based on this prior study, it was hypothesized that some kind of implicit learning takes place while solving isoproblems, since problem solvers are not aware of solving a series of problems that require identical moves. Hence, an exploratory study with a small sample size was conducted, testing a patient group which would likely have problems with implicit memory, namely, patients with idiopathic Parkinson's disease. If this patient group would not show any improvement across isoproblems, this would be a first indication that the iso-effect might actually be based on implicit learning. The present study could then serve as a starting point for further, higher-powered studies.

Parkinson's disease (PD) is a progressive, idiopathic neurological disorder related to the loss of dopaminergic cells in the substantia nigra. In addition to motor impairments, cognitive deficits are observed during disease progression, among them deficits in problem-solving and tasks related to executive functions. PD affects the basal ganglia and has previously been connected to impairments of implicit memory (Ruitenberg et al., 2015). The basal ganglia receive projections from the substantia nigra with dopamine as neurotransmitter, so a loss of dopaminergic cells in the substantia nigra may lead to impairment of implicit memory. The ToL has often been used in patient populations. Specifically for PD patients, performance deficits have been reported (e.g., Lange et al., 1992; Owen et al., 1995). Culbertson et al. (2004) compared a large group of PD patients to healthy controls and found longer solution times, more moves, and more rule violations in the Tower of London-Drexel (ToL$^{DX}$, an improved variant of the original ToL with slight modifications).

The main goal of this exploratory study is to examine the impact of isoproblems on problem-solving performance and to replicate the previously reported learning effect ("iso-effect", Faber et al., 2009). Since the iso-effect is probably based on implicit learning, it should be absent or reduced in participants with impaired implicit learning such as patients with PD. It is thus hypothesized that the iso-effect will recur in a healthy control group, but not in PD patients. The hypothesis that there is a lack of awareness for isoproblems will also be addressed. Finally, the feasibility of a newly developed ToL tablet version for PD patients will be assessed. At issue is whether patients in advanced stages of the disease will be able to master the cognitive demands of the task and whether their motor impairments still allow them to control the game by using a touchscreen and a special pen.

## Method

### *Participants*

A sample of 20 participants was tested, ten Parkinson patients and ten healthy controls. The patients were recruited by screening the outpatient files of the Department of Neurology, and the patients' spouses served as controls. One participant from each group had to be excluded from the analysis: the control person because of too-advanced age (20 years older than the next-oldest participant) and the patient because she differed extremely from the other patients with regard to her severely impaired motor skills. Including her would have compromised the homogeneity of the patient group. This results in a final sample size of $n = 9$ for each test group. In the patient group, age ranged from 51 to 74 years ($M = 66.1$, $SD = 7.42$). In the control group, the range was from 40 to 71 ($M = 59.0$, $SD = 10.67$). A t-test confirmed that groups were matched in terms of age, $t(16) = 1.64$, $p = .12$, and gender, $t(16) = 1.46$, $p = .17$.

### *Characterization of Patient Sample*

The diagnosis of idiopathic Parkinson's disease was established by neurologists who also rated the patients for severity of symptoms using the Hoehn and Yahr scale. The following additional information was collected: duration of disease, prescribed drugs, last intake and dose. Patients were also asked if they had an implanted brain stimulator.

### *Problem-Solving Task*

The Tower of London is a transformation task. Participants are required to rearrange a set of three balls placed on three rods from their initial position into another specified goal configuration. Rods differ in height and can therefore hold only one, two or three balls, respectively. The balls are colored blue, red and green. A computerized version of the game was used for testing which had been developed by Hinz et al. (2009) after the model of the original wooden game by Shallice (1982). The physical appearance, the instructions given, and the selection of problems was strictly oriented on Shallice's original version. A screenshot is shown in Figure 1. This ToL version runs on an easy-to-handle tablet PC that can also serve as a clinical bedside test. The balls are moved from one rod to the other by tapping on the touchscreen with a pen. Participants select a ball which is then highlighted with a red frame. In order to move the ball to another rod, they simply tap at the chosen rod. The ball is then moved automatically from one rod to the other. For each problem, the minimum number of moves required to solve it is shown below the start configuration on the screen and participants are asked to solve the task in the indicated number of moves.

### *Selection of Problems*

The optimal solution path ranges from one to a maximum of eight moves in any possible ToL problem. The ToL problem space contains 210 problems that are spatially unique (Berg & Byrd, 2002), as they differ from all other problems in at least one move in their optimal pathway. Every one of them has five "twins"

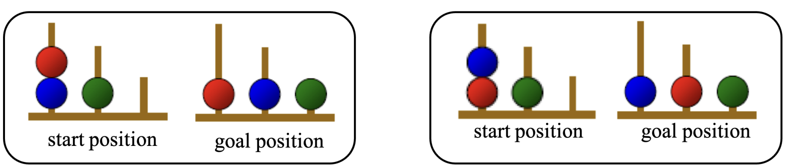


**Figure 2.** *Two Tower of London isoproblems*

which are called “isoproblems” (Berg & Byrd, 2002). Isoproblems require identical moves as they have the same start and goal position, but the colors of the balls are permuted (see Fig. 2). Those sets of isoproblems have the same level of difficulty (assuming there is no color preference whatsoever) but look different to the observer.

The selected problems corresponded to Shallice’s original range of problems of two to five moves, see Appendix for a detailed list. Eleven problems were implemented. The isoproblems were taken from a set with five moves. To keep the total number of problems small, only five isoproblems were taken from the set (although one iso-set always consists of six problems). The chosen isoproblem was explicitly mentioned by Shallice (1982, p. 204) as being one of the harder problems.

Goal hierarchy: ToL problems can also be categorized according to their start and goal configurations (see Fig. 3). Depending on the configuration used, the sequence of goal moves may be completely ambiguous (flat), partially ambiguous (partial tower) or unambiguous (tower). That is the reason why problems with the same minimum number of moves but different structural properties require different planning abilities and thus have different levels of difficulty (Kaller et al., 2011). As flat configurations seem to be the most difficult ones (Kaller et al., 2004), they were not used in the present study in order to keep difficulty at a level appropriate for patients.

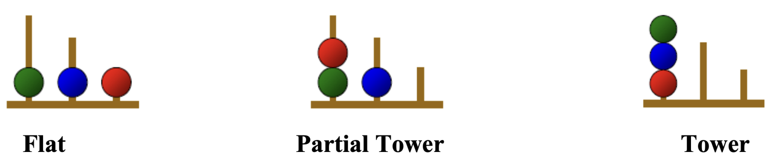


**Figure 3.** *The three possible start and goal configurations for the Tower of London*

### *Isoproblems Compared with a Non-isomorphic Control Problem*

In addition to the set of five isoproblems, one more five-move problem was selected (see Appendix, Problem #8, non-isomorphic to the other five-move problems). The idea was to compare the isoproblems to another 5-move problem with similar difficulty. The challenge was to find a comparable problem, because the difficulty of a problem is hard to define. Therefore, a problem from the previous study (Faber et al., 2009) was chosen, based on the performance of a sample of 40 healthy controls; see Table 1 for a comparison between the isoproblem and the control problem.

**Table 1.** *Comparison of ToL data between two problems (one now used as isoproblem, the other as control problem) from the Faber et al. study (2009)*

| Performance measure | Isoproblem | Control problem |
|---|---|---|
| Moves | 5.85 | 5.88 |
| Efficiency Value | 0.88 | 0.92 |
| Solution Time | 64.8 | 61.7 |

*Note.* t-tests for repeated measures showed that the two problems did not differ significantly in any performance measure. This data was obtained from 40 healthy controls, aged 46 to 70 years.

### *Procedure*

Participants were tested individually. Instructions were given in written form and further explained by the experimenter. Speed and accuracy were equally stressed. A practice trial of four problems was performed to get used to pen and touchscreen. Participants completed eleven problems in one session of approximately 45 minutes. Directly after the last problem, to check for their awareness of isoproblems, participants were asked: “Have you noticed anything concerning the last two problems?” Awareness of isoproblems was assumed if the response was “They followed the same principle” or similar statements. If participants had not noticed anything special, a second question was asked: “Have you maybe noticed that the last two problems were the same, only with different colors?". In this case, a positive answer was coded as "awareness after cue".

### *Tower of London Performance Measures*

ToL problem-solving can be assessed on various dimensions of performance. Berg and Byrd (2002) divide all possible measures into four groups: a) success and accuracy; b) efficiency; c) speed; d) strategy measures and rule breaks. They suggest using a complete set of measures from these categories to obtain a comprehensive estimate of individual performance. Following those recommendations, seven performance measures were chosen. The computerized ToL version automatically recorded those parameters.

1. *Solution Time:* Amount of time (in seconds) needed to solve a problem. It consists of two phases: Initiation (for thinking about the problem) and completion (to execute the moves), see Figure 4.
2. *Initiation Time:* Time from presentation of a problem to the first move (time needed for planning). As recommended by Berg and Byrd (2002), the Initiation Time period ends with the second tap of the first move (when the problem solver selects the rod where the ball should be placed); see Figure 4. This seems useful because even after having selected a ball to be moved,

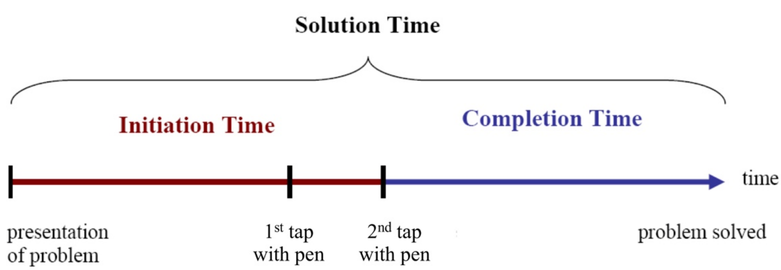


**Figure 4.** *Solution Time for one problem consists of Initiation Time plus Completion Time*

problem solvers may continue planning until they eventually choose a rod to place that ball on.

3. *Completion Time:* Time from first to last move (i.e., when the solution is completed).

4. *Efficiency Value:* There can be more or less efficient solutions to a problem. Efficiency was calculated by dividing the minimum number of moves by the actual number of moves needed. The Efficiency Value therefore ranges between 0 and 1, with a value of 1 indicating optimal performance.

5. *Moves:* Number of moves needed to solve a problem.

6. *Errors:* Every rule violation (e.g., attempts to put a ball on a rod that is already full) was counted as error.

7. *Awareness of Isoproblems:* Problem solvers' responses to the question about awareness of the last two isoproblems were coded as follows: no awareness, awareness after cue, awareness without cue.

Parameters 1, 2 and 3 measure speed, 4 is a measure of efficiency, and Parameters 5 and 6 provide information about the strategy used.

## Results

### *Awareness of Isoproblems*

Most participants (66.7 % of the sample) did not realize that they had solved isoproblems. Only 22.2 % of all participants recognized instantly that the last two problems could be solved with the same sequence of ball movements and could tell that they differed only by a transformation of ball color. Another 11.1 % realized it after they had received an additional cue, as detailed in the procedure. PD patients did not differ from controls in their awareness of isoproblems.

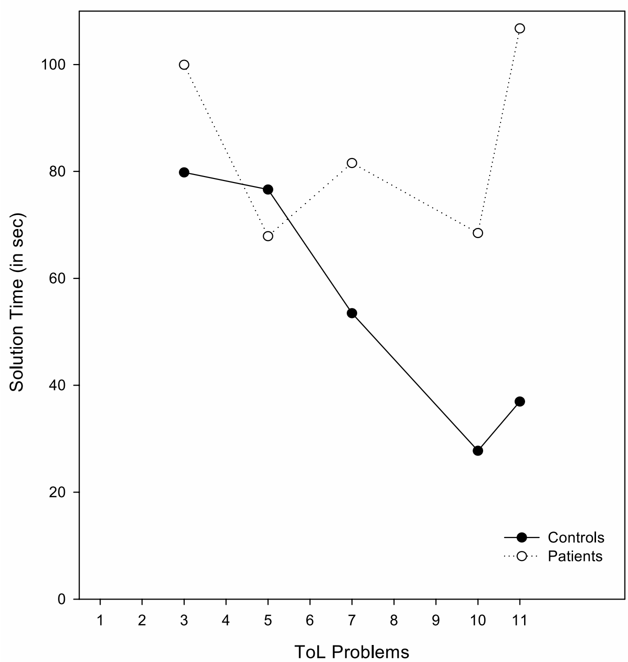


**Figure 5.** *Mean Solution Time for each of the five isoproblems (controls in black, patients in white)*

## *Comparison Patients Versus Controls*

All eleven problems were solved by all participants. As expected, patients' problem-solving performance was lower compared to controls. A two-way t-test for independent samples showed significant differences between the two test groups with respect to the following variables: Solution Time, $t(16) = 2.80$, $p = 0.02$; Completion Time, $t(16) = 2.87$, $p = 0.02$; Moves, $t(16) = 2.34$, $p = 0.04$; and Efficiency Value, $t(16) = 2.76$, $p = 0.02$. The difference in committing errors was not significant with $p = 0.056$. Patients had longer overall solution times ($M = 78.6$ secs, $SD = 37.1$) than controls ($M = 42.7$ seconds, $SD = 10.2$) and needed more time (Completion Time: $M = 62.8$ secs, $SD = 35.9$) to execute the movements than controls ($M$ = 27.5 seconds, $SD$ = 8.5), but there was no difference between the groups with regard to the variable Initiation Time where both groups had a mean value of 15 seconds. Patients required more moves ($M$ = 7.2, $SD$ = 2.3) than controls ($M$ = 5.4, $SD$ = 0.6) and had a lower efficiency ($M$ = 0.74, $SD$ = 0.1) in solving problems than controls ($M$ = 0.88, $SD$ = 0.1).

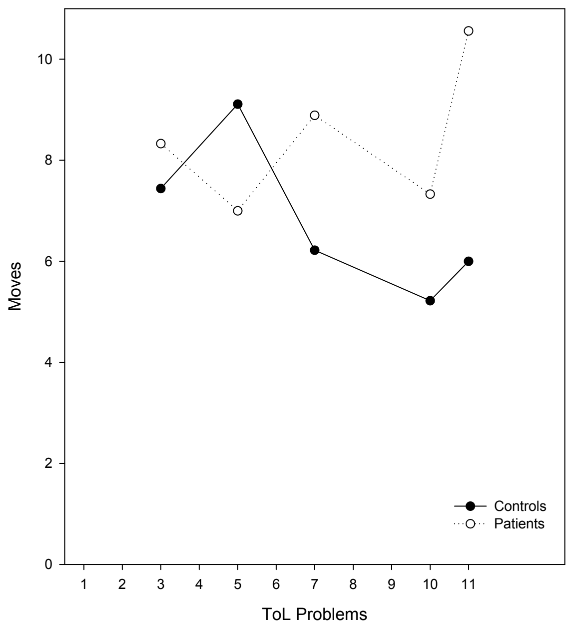


**Figure 6.** *Mean number of moves for each isoproblem (controls in black, patients in white)*

## *Iso-Effect*

Separately for each test group, performance across the five isoproblems was compared via ANOVA for repeated measures. There were no significant differences between the five isoproblems for any performance variable in the patient group, supporting the hypothesis that no iso-effect would occur for PD patients. In contrast, controls showed improved performance across the five isoproblems, with significant effects for the following variables: Solution Time, $F(4, 32) = 2.78$, $p = 0.04$, $\eta_p^2 = 0.26$; Moves $F(4, 32) = 3.23$, $p = 0.03$, $\eta_p^2 = 0.29$; and Efficiency Value, $F(4, 32) = 3.97$, $p = 0.01$, $\eta_p^2 = 0.33$. Controls became faster from isoproblem to isoproblem. In Figure 5, the learning curve of controls can be compared to the W-shaped performance of patients who did not improve their performance.

A similar iso-effect, shown in Figure 6, could be observed for the number of moves needed to reach a solution. Likewise, participants from the control group were able to find increasingly efficient solutions across isoproblems; see Figure 7.

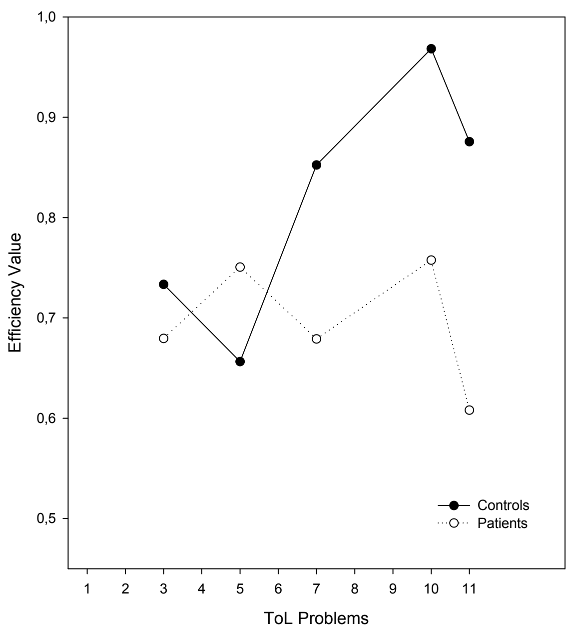


**Figure 7.** *Mean efficiency for each isoproblem (controls in black, patients in white)*

## *Isoproblems Compared with a Non-isomorphic Control Problem*

As described in the section on problem selection, one five-move control problem was presented in addition to the set of five-move isoproblems. The idea was to compare performance for isoproblems with another five-move problem of similar difficulty. In Figure 8, mean Solution Times for the isoproblems are plotted together with the non-isomorphic control problem. If the observed decrease in Solution Times across isoproblems was caused by a general learning effect, the presentation of another, non-isomorphic problem of the same difficulty should not interrupt the learning curve. But the control problem (marked by an arrow) does not fit onto the

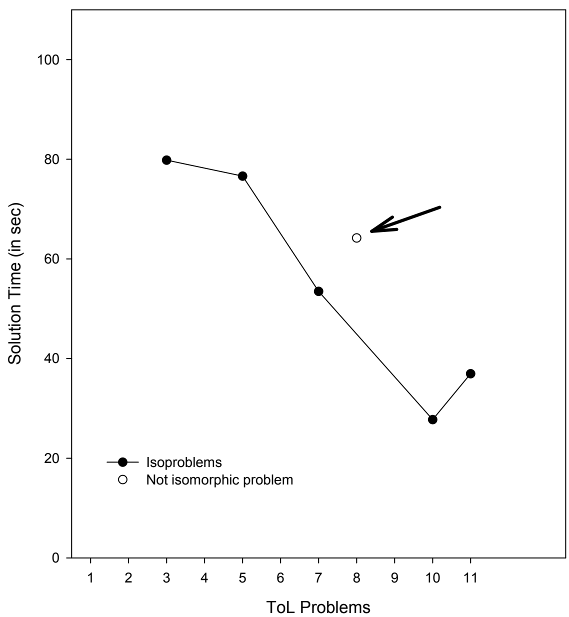


**Figure 8.** *Solution Time learning curve for isoproblems. The non-isomorphic problem (marked by an arrow) does not fit onto the curve.*

curve—instead there is a drop in performance, reflected in longer Solution Times. This can be taken as an indication that the iso-effect is specific to isoproblems and not due to general learning. The same pattern is observed for the variables Moves and Efficiency (Fig. 9 and 10). The data presented here is based only on control participants because, for patients, no iso-effect and, hence, no learning curve was found.

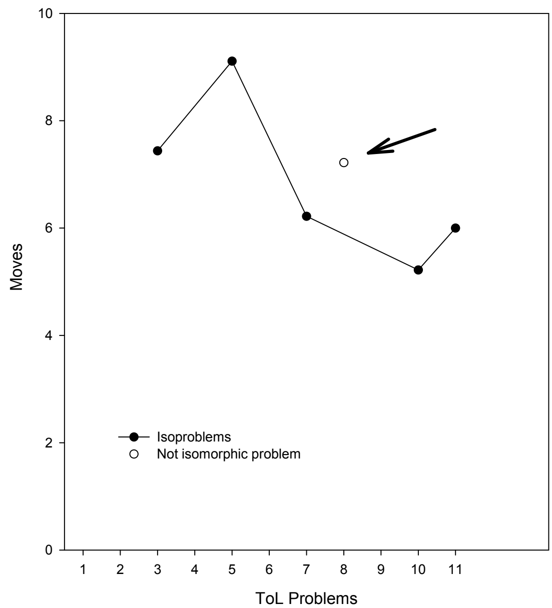


**Figure 9.** *Move learning curve for isoproblems. The non-isomorphic problem (marked by an arrow) does not fit onto the curve.*

## Discussion

In the present exploratory study, the previously found iso-effect (Faber et al., 2009) occurred again for three main ToL performance measures. Control participants learned from isoproblem to isoproblem with regard to solution time, moves and efficiency. They needed less time, fewer moves and their solutions became increasingly efficient. This is in contrast to patients, who did not improve their performance in any variable.

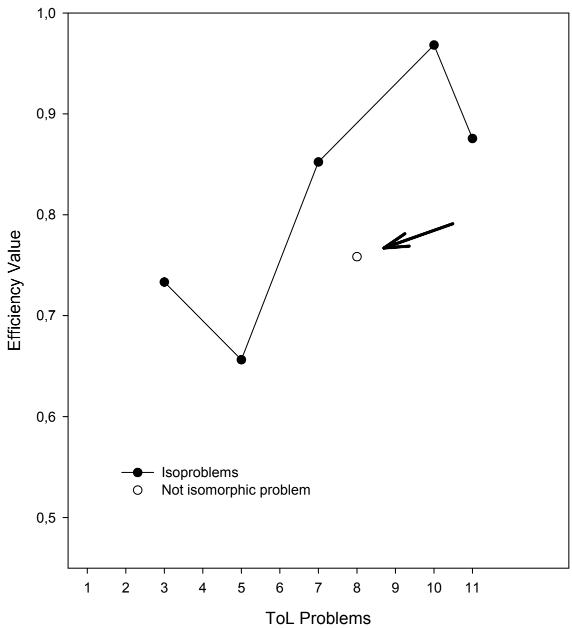


**Figure 10.** *Efficiency learning curve for isoproblems. The non-isomorphic problem (marked by an arrow) does not fit onto the curve.*

In accordance with prior work (Faber et al., 2009; Johns, 2005), only one third of the sample was aware of the repetition of isoproblems, supporting the hypothesis of a lack of awareness for isoproblems. Thus, it seems that problem solvers learned without realizing it. It has been suggested (Berg & Byrd, 2002; Kaller et al., 2011) that isoproblems could be very useful for repeated assessment. Implementing isoproblems in subsequent testing sessions offers the possibility of comparing participants' performance on functionally identical problems. In the present study, most participants were not aware of the similarity of these problems, although the repetition took place within minutes. It can therefore be assumed that, in different testing sessions with more time in between, there would most likely be no awareness of solving the same problems again and again. This demonstrates the great value of isoproblems for neuropsychological testing.

While only based on a very small sample, the present results seem to support our main hypothesis and prediction: the iso-effect recurred in the healthy control group but not in the patient group. Why did PD patients not show the learning effect? Why could they not benefit from the repeated presentation of the same problem, in contrast to controls? Is this deficit specific to PD patients, or would other patients show the same pattern? Further research using higher-powered studies and including other patient groups is needed to answer these questions. For now, the present findings are regarded as a first indication that isoproblems do actually measure implicit learning and that the reason why PD patients did not show the iso-effect lies in their impairment of implicit memory.

It is important to distinguish the iso-effect from general learning caused by familiarity with the task and by solving a series of eleven problems. It is argued here that the iso-effect is distinct from general learning in two ways: It is based on implicit learning and occurs after very few repetitions (the second isoproblem was solved significantly better than the first one). Evidence for the first claim is given by the fact that most participants showed no awareness of solving the same problem and by the finding that PD patients (i.e., patients with impaired implicit memory) did not show the effect. The learning effect observed by Johns (2005) occurred while a series of 48 problems was solved, but participants in the present study improved while solving only five isoproblems.

The comparison with a non-isomorphic control problem further supports the idea that the iso-effect is specific to isoproblems and not due to a general learning effect as proposed by Johns (2005). If the improvement from isoproblem to isoproblem was caused by general learning, the presentation of another, non-isomorphic problem of the same difficulty should not interrupt the learning curve, since problem solvers should be able to benefit from prior exposure to comparable problems and, therefore, improve their performance further. Instead of such continuous improvement, a drop in performance for the non-isomorphic problem was observed.

As expected, the control group performed better overall than the patient group. However, this comparison yielded some findings that deserve further discussion. The differences in solution time and completion time between PD patients and controls should not be interpreted to the effect that patients needed more time to think about the problem. As there was no significant difference in initiation time, it seems reasonable that patients only needed more time to execute the movements—and that this caused the difference in overall solution time, which consists of initiation and completion time.

Interestingly, the same pattern of results was obtained in the previous study (Faber et al., 2009) when comparing younger with older participants. Older participants (like the patients) needed more time to execute the movements, but did not differ from younger participants with regard to initiation time. In that study, it was concluded that motor skills rather than cognitive skills seemed to distinguish the young from the old in the computerized version of the ToL task. This conclusion must be reconsidered, because in contrast to the older control group who was as good as the younger one in finding efficient solutions, patients differed substantially from the other group in the quality of their solutions. For patients, it is not just motor skills that distinguish them from controls, but they also show cognitive deficits resulting in less optimal solutions.

The present results suggest that PD patients are comparable to healthy controls with respect to the amount of planning done. However, the same amount of planning does not result in the same quality of solutions—an unexpected finding which requires discussion. On average, the efficiency of controls was much higher than the efficiency of patients, and approached the optimal value of 1, indicating that controls solved more problems in the minimum number of moves. Although both groups dedicated the same amount of time to planning, controls were able to find more efficient, better solutions. Does the length of the planning phase have no impact on the quality of solutions? Did patients decide for the wrong solution paths during their planning phase? Or did patients not plan at all before executing the first move, but merely used this time for general orientation (identifying the goal configuration, thinking about the rules…)? Judging from the informal observation of patients' behaviour during the task, the last possibility seems to be the most plausible one. Obviously, other experimental procedures, such as thinking-aloud, are needed to back up these observations. In any case, this interesting finding needs to be further investigated in future studies.

Another aspect to consider is the true nature of the deficits shown by PD patients. Which underlying functions are impaired? Is it really a cognitive deficit? It could also be argued that deficits in visuospatial perception cause the poor performance, since visuospatial impairments have been reported in PD patients (Boller et al., 1984; Kerai et al., 2012; Ransmayr et al., 1987). For further research, it is thus recommended to implement an additional test to assess patients' visuospatial abilities.

Obviously, due to the small sample size, the present study must be interpreted with caution. It was intended to test whether the iso-effect would be found again and whether PD patients would be a good target population for investigating this learning effect. As it stands, the present results are encouraging and will hopefully serve as starting point for further studies into the iso-effect and the possible underlying mechanism of implicit memory.

A final question was whether the newly developed ToL tablet version (where the game is controlled via touchscreen and special pen) would be feasible for PD patients. In the present sample, all patients were able to master the motor demands of the task. However, this finding might be limited to PD patients with a deep brain stimulator (seven out of nine patients had one implanted). Considering the fact that the brain stimulator considerably decreases the tremor, it remains unclear if patients without this treatment would be able to complete the task. However, the two patients from our sample without a brain stimulator succeeded as well.

In accordance with previous studies (Culbertson et al., 2004), the effectiveness of the ToL in differentiating between patients with Parkinson's disease and healthy controls could be demonstrated. PD patients took more time to solve the problems, they required more moves and their solutions were less efficient compared to controls. Hence, the ToL puzzle on a tablet PC could also contribute to the identification of PD patients.

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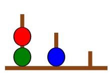
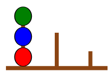
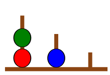
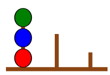
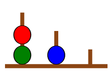
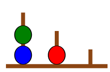
**Appendix.** *ToL problems used*

| Start position | Goal position | Min. moves | Order | Comment |
|---|---|---|---|---|
| RG/B/0 | 0/GB/R | 2 | Nr. 1 | Shallice |
| RG/B/0 | BG/R/0 | 3 | Nr. 2 | Shallice |
| <br>RG/B/0 | <br>GBR/0/0 | 5 | Nr. 3 | 1st isoproblem, Shallice |
| RG/B/0 | G/BR/0 | 3 | Nr. 4 | Shallice |
| <br>GR/B/0 | <br>GBR/0/0 | 5 | Nr. 5 | 2nd isoproblem, Shallice |
| RG/B/0 | B/GR/0 | 4 | Nr. 6 | Shallice |
| RB/G/0 | BGR/0/0 | 5 | Nr. 7 | 3rd isoproblem, Shallice |
| <br>RG/B/0 | <br>GB/R/0 | 5 | Nr. 8 | Shallice |
| RG/B/0 | BR/0/G | 4 | Nr. 9 | Shallice |
| BG/R/0 | GRB/0/0 | 5 | Nr. 10 | 4th isoproblem, Shallice |
| BR/G/0 | RGB/0/0 | 5 | Nr. 11 | 5th isoproblem, Shallice |

*Note.* Capital letters refer to the color of the ball. For example, RG/B/0 refers to the ToL state where the red ball is lying on the green ball on the left rod, the blue ball is positioned on the middle rod and the right rod is empty (compare problem Nr. 3).