



The effect of constant versus varied training on transfer in a cognitive skill learning task: The case of the Tower of Hanoi Puzzle



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ABSTRACT

The differential effect of constant versus variable training conditions on acquisition and transfer has been demonstrated primarily in perceptual motor skills. In the present study, this effect was tested on 84 young adults using a cognitive skill learning task – the Tower of Hanoi Puzzle. The advantage of this task is that it allows testing the effect of the two training protocols on transfer by separately analyzing accuracy of the task solution, speed of reaching the correct solution and time planning before beginning to solve the task. Participants were divided into two groups. The “constant training” group practiced the task for 10 consecutive trials with identical configuration in terms of the “start” and “end” peg; followed by an 11th trial with a new configuration of the task (i.e., transfer). The “varied training” group practiced for 10 consecutive trials with different configurations, followed by a new configuration of the task compared with the varied training group. These findings support the notion that varied training leads to the development of a schematic representation of the task solution, thus transfer is facilitated. These results have important implications in terms of the optimal learning conditions for adults while coping with cognitive problem-solving tasks.

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The factors that enable transfer following skill acquisition have been studied extensively in learning and memory literature (Speelman & Kirsner, 2001). Baldwin and Ford (1988) view transfer as the primary issue in skill learning research. In fact, Schmidt and Bjork (1992) claim that transfer is a better index of learning than the acquisition process itself. In many cases, the goal of skill learning is to enable transfer of variations of the acquired skill in real life situations such as the work setting (Holladay & Quinones, 2003). Another example is when children learn to solve mathematical problems at school, the teacher hopes that they will apply these skills to similar problems that were not necessarily practiced in class (Hatano & Inagaki, 1986; Verschaffel, Luwel, Torbeyns, & Van Dooren, 2009). The issue of transfer has been studied for over a century (for historical reviews see Adams, 1987; Baldwin & Ford, 1988). Most theories of transfer ascertain the requisite of certain similarity between the learned and new task, either in terms of stimuli and responses (Osgood, 1949) or shared action production rules (Singley & Anderson, 1989).

Hatano and Inagaki (1986) and Schmidt and Lee (2011) claim that although transfer is typically expected following training, there are cases in which there is no need or expectation to transfer the skill to

other situations (Schmidt and Lee give the examples of archery and bowling). Other researchers however, do not accept this dichotomy and stress the need for constant training at the early phase of skill acquisition in order for varied training to yield the advantage expressed by better transfer (Lai & Shea, 1998, 1999; Lai, Shea, Wulf, & Wright, 2000; Shea, Lai, Wright, Immink, & Black, 2001).

Several researchers have attempted to identify the factors affecting the generalizability of acquired skills. Schmidt (1975), for example, proposed the “schema theory of discrete motor skill learning”. Schmidt and Lee (2011) view schema as a rule learned during the acquisition process. “The rule is a relationship between all the past environmental outcomes that the person produced and the values of the parameters that were used to produce those outcomes. This rule is maintained in memory and can be used to select a new set of parameters for the next movement situation – even a novel variation – that involves the same motor program” (p. 371).

Schmidt (1975) recommends engaging in varied training to enable the development of schema that would yield better transfer (“e.g., jump over an object in as many ways as possible” p. 257). Constant training reinforces a rigid and specific sequence of actions without requiring an understanding of the abstract solution or representation of the task. However, adopting a particular sequence of actions during varied training would not be effective. Instead, varied training would lead (intentionally or unintentionally) to a search for a more generalized

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solution or rule that could be applied to a range of variations of the task. The variety of tasks encountered are presumed to yield a schema, i.e. a more abstract representation of the motor skill, which would enable better transfer of the learned skill (Green, Whitehead, & Sugden, 1995; Schmidt, 1975). In other words, if a problem schema is not developed during practice and the participant fails to notice the similarity between the examples and the subsequent novel task, transfer abilities are limited (Chen, 1999).

Numerous studies tested specific perceptual-motor tasks and confirmed that varied training results in better generalization of the learned skill than constant training. Heitman, Pugh, Kovaleski, Norell, and Vicory (2005) showed that varied practice of a pursuit rotor task (three different speeds) resulted in better transfer than specific (single speed) practice. Roller, Cohen, Kimball, and Bloomberg (2001) used visual displacement lenses to test the effect of varied versus constant training on adaption to visuo-motor discordance. Their results show that varied training (i.e. using multiple sets of lenses) yielded better increased adaptability to a novel visuo-motor situation than constant training (i.e. using one set of lenses). Green et al. (1995) showed that varied training for a forehand stroke with a racket resulted in better 'out of range' transfer than specific training. Yao, Cordova, De Sola, Hart, and Yan (2012) tested the effect of varied versus constant training on a real-life motor task, i.e. wheelchair propulsion. Consistent with previous findings, varied training (two speeds) resulted in greater improvement of propulsive efficiency than constant training (single speed). However, a critical review by Van Rossum (1990) found that empirical support for the "variability hypothesis" is not entirely solid. For example, several of the studies that claim to support this hypothesis did not demonstrate a learning effect in the first place. Thus, findings reported above in support of the "variability hypothesis" should be interpreted cautiously as the findings are not as conclusive as they may seem.

Previous studies have demonstrated the importance of distinguishing between perceptual-motor and cognitive skill learning tasks (Vakil & Hoffman, 2004). While the differential effect of type of training (i.e. varied vs. constant) on acquisition and transfer has been well studied in regard to perceptual-motor skills, literature on cognitive skills is very scarce. In a series of studies, Chen and colleagues (Chen, 2002; Chen & Klahr, 1999; Chen & Mo, 2004) addressed this question using a problem solving task called Luchins' Water Jar Problems. In this task, children are presented with three water jars with different capacities. Their task is to fill up one of the jars with a specific amount of water using these three jars. The researchers demonstrated that children trained with various versions of the task (e.g. different rules to solution) showed better transfer to a new version (e.g. untrained rule) of the task than those with less varied training, though the children given less varied training exhibited slower initial learning. In his review, Rohrer (2012) distinguishes between *blocked* and *interleaved* concept exposure, which resembles the distinction between *constant* and *varied* training, respectively. The advantage of interleaved over blocked exposure was demonstrated in a variety of tasks such as category induction learning and discrimination learning. In a more recent study, Rohrer, Dedrick, and Burgess (2014) showed the benefit of interleaved practice while learning mathematics.

Though, Schmidt's schema theory refers to a generalizable *motor* program or rule, the TOHP case presented in this study refers to a generalized *cognitive* program or rule. Consistent with the above definition of motor skill schema by Schmidt and Lee (2011), the cognitive schema is a rule or algorithm that can be applied to any configuration of the TOHP. In fact, computer scientists are often instructed to write an algorithm based on a recursive law as explained above for solving the TOHP.

Hence, unlike the literature on motor skill learning, the literature on the effect of learning procedure on transfer in cognitive skill learning is very limited. Findings on cognitive skill learning could have very important implications on the teaching methods used for all ages - from primary school to graduate school. The main goal of this study is to test

the effect of training procedures, i.e. constant versus varied, on transfer in the Tower of Hanoi Puzzle (TOHP) a well-established cognitive skill learning task (Anderson, Albert, & Fincham, 2005; Beaunieux et al., 2006; Schiff & Vakil, 2015; Vakil & Hoffman, 2004). It is hypothesized that the "constant training" group would perform better at the acquisition phase than the "varied training" group. On the other hand, the "varied training" group will develop a more abstract solution which will facilitate transfer, therefore this group will more easily transfer to a new configuration than the "constant training" group.

The TOHP is a problem solving task that requires planning and sub-goal management and is a non-verbal task that does not depend on prior knowledge such as mathematical background. Performance on the TOHP reflects various cognitive processes such as planning, problem solving, inhibition, self-regulation and monitoring (Strauss, Sherman, & Spreen, 2006). The use of the TOHP generates various measures of speed of solution, accuracy and planning time. Thus, this task enables testing the effect of the two training protocols on transfer by separately analyzing accuracy, speed and planning time.

As will be explained in more detail in the Procedure section, the task can be presented in six different configurations. The various configurations are at exactly the same level of difficulty (i.e., require the same number of moves to solution). Transfer from one configuration to another requires abstract representation abilities and flexible thinking that enable application of the same underlying principle.

1. Method

1.1. Participants

A total of 84 individuals participated in this study. In the "constant training" group: $n = 44$ (19 males), mean age 22.75 years (range 19–32 years, $SD = 2.82$), mean education 13.45 years ($SD = 1.34$). In the "varied training" group: $n = 40$ (17 males), mean age 23.63 years (range 18–32 years, $SD = 3.58$), mean education 13.91 years ($SD = 1.72$). The groups did not significantly differ in age, $t(82) = 1.25$, $p = .22$, or in education, $t(82) = 1.37$, $p = .17$. Participants were mostly undergraduate students at Bar Ilan University who participated in the experiment for class credit. The others were volunteers or participants who were paid for their participation. Written informed consent was obtained from all participants for a protocol approved by the Bar Ilan University Institutional Review Board.

1.2. Tasks and procedure

1.2.1. Tower of Hanoi Puzzle

Three pegs appeared on the screen, numbered 1 to 3. Four disks were arranged on one of the pegs according to size with the largest disk at the bottom. Participants were instructed that the goal was to move the disks, using the keyboard, from the initial peg to another peg (determined by the task condition) in a minimum number of moves and as quickly as possible. They were also told that they had to adhere to the following rules: only one disk could be moved at a time, no disk could be placed on a smaller one, and the middle peg had to be used. Participants were not informed that a transfer task would follow the acquisition phase. The optimal solution for four disks requires 15 moves. The computer automatically recorded the number of moves required to solve the puzzle, time to solution, the average time per move, and time of first move.

During the acquisition phase, both the constant and varied training groups solved 10 consecutive trials of the TOHP. This was followed by a transfer phase - the 11th trial. However, the procedure in which the task was administered differed between the two groups. The TOHP can be played in six different configurations as determined by the initial peg and the final peg; 1 to 3, 1 to 2, 2 to 3, 3 to 1, 2 to 1, & 2 to 3.

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