Learning and Individual Differences 39 (2015) 164–171

Contents lists available at ScienceDirect

Learning and Individual Differences

journal homepage: www.elsevier.com/locate/lindif

# Age differences in cognitive skill learning, retention and transfer: The case of the Tower of Hanoi Puzzle[☆]

Rachel Schiff [a,*], Eli Vakil [b]

[a] Learning Disabilities Studies and Haddad Center for Dyslexia and Learning Disabilities, School of Education, Bar-Ilan University, 52900 Ramat-Gan, Israel
[b] Psychology Department and the Leslie and Susan Gonda (Goldschmied) Multidisciplinary Brain Research Center, Bar-Ilan University, Ramat-Gan, Israel

A R T I C L E  I N F O

*Article history:*
Received 19 February 2014
Received in revised form 18 November 2014
Accepted 28 March 2015

*Keywords:*
Skill learning
Age
Tower of Hanoi
Schema
Cognitive tasks

A B S T R A C T

The current study aimed to investigate cognitive skill learning using the Tower of Hanoi Puzzle (TOHP). This study expanded use of the TOHP to measure baseline performance, learning rate, offline learning (following overnight retention), and transfer, comparing two age groups (Grades 3 and 6) of participants ($n = 60$). Several measures were analyzed from 14 trials with the TOHP over two sessions: accuracy, processing speed, and planning. Findings revealed a trade-off between accuracy and time in both baseline performance and the learning phase for both groups, whereas the results for offline learning indicated an advantage for the older group in planning after a night's sleep. Transfer seemed to be most affected by age as reflected in the younger group's more shallow learning and limited problem schema acquisition, which resulted in fewer long-lasting effects compared to the older group. Findings are consistent with the current literature on frontal lobe and executive function development.
© 2015 Elsevier Inc. All rights reserved.

## 1. Introduction

Skill learning is a well-researched educational psychology topic. It is broadly described as the improvement of a skill over time as a function of practice. The process of skill acquisition begins with the acquisition/learning phase which includes the first engagement with the task (known as baseline performance), and proceeds with repeated practice of the procedure. This phase is accompanied by rapid improvements in performance that can be seen within seconds to minutes. The improvements during initial task practice follow a curve, where performance gradually reaches an asymptote (i.e., power function), and with sufficient practice the learned skill could reach automaticity (Stickgold & Walker, 2005). In this context, automaticity refers to a shift from controlled performance to more efficient performance with reduced demands on attention (Shiffrin & Schneider, 1977) and a corresponding shift in brain networks that support performance (Chein & Schneider, 2005; Jueptner & Weiller, 1998). Skill learning and mastery are usually tested by measuring accuracy and completion speed during the learning phase of a repeatedly presented task (Moscovitch, Goshen-Gottstein, & Vierzen, 1994).

### 1.1. Skill learning

Previous research on the development of skill learning has frequently employed the Serial Reaction Time (SRT), and other motor learning tasks which are commonly used perceptual task for assessing sequence learning (e.g. Meulemans, van der Lindenm, & Perruchet, 1988). Findings from research using this paradigm has provided evidence for the view that age does not play a role in the context of perceptual skills learning tasks, as numerous studies employing the SRT task demonstrated non-significant differences between groups of children and adults (e.g., Meulemans et al., 1988; Thomas & Nelson, 2001). Further studies examining motor skill learning in children and early adolescents, with an emphasis on learning benefits found similar evidence that implicit skill learning is not developmentally linked (Dorfberger, Adi-Japha, & Karni, 2007; Fischer, Wilhelm, & Born, 2007; Savion-Lemieux, Bailey, & Penhume, 2009). The goal of this study is to assess the role of age in a cognitive skill learning task in two age groups spanning childhood and early adolescence. These two specific age groups were selected because brain structure and function undergo significant maturation between these two age periods; namely, prefrontal systems are immature during early childhood, yet begin to emerge during early adolescence (Huttenlocher & Dabholkar, 1997).

Skill learning can also be assessed via cognitive skill learning tasks (Beaunieux et al., 2006). When such a task is employed just one time, it primarily measures executive functions (Lezak, Howieson, Loring, Hannay, & Fischer, 2004), whereas its repeated administration over many learning sessions mainly assesses cognitive skill learning (Beaunieux et al., 2006). Moreover, multiple engagement cognitive skill learning tasks enable investigation of individuals' pre-learning planning ability and their post-learning improvements in offline learning, which means further improvements without any further learning, and transfer.

[☆] This manuscript has not been published elsewhere and has not been submitted simultaneously for publication elsewhere.
* Corresponding author. Tel.: +972 3 5318705; fax: +972 3 5351049.

http://dx.doi.org/10.1016/j.lindif.2015.03.010
1041-6080/© 2015 Elsevier Inc. All rights reserved.

A few research studies have employed cognitive tasks to examine skill learning in patient populations such as: amnesics (Cohen & Squire, 1980; Schmidtke, Handschu, & Vollmer, 1996; Winter, Broman, Rose, & Reber, 2001), patients with lesions to the basal ganglia (Vakil, Blachstein, & Soroker, 2004), Parkinson's (Vakil & Harishanu-Naaman, 1998) or frontal lobe patients (Guevara et al., 2012). In the above studies, cognitive skill learning tasks were used for typical populations serving as control groups for a population with a disorder (e.g., Vakil & Harishanu-Naaman, 1998).

To date, very few studies have documented the process of skill learning for typically developing children and adolescents using a cognitive skill learning task the latter is often used to assess cognitive abilities (e.g. problem solving). Examining skill learning using a repeatedly practiced cognitive task enables prediction of participants' learning abilities of abstract rules in addition to their baseline performance (which is measured by one time tasks). It also allows prediction of participants' post-learning abilities during offline learning and transfer.

### 1.2. The Tower of Hanoi task

One such task enabling assessment of high-order cognitive problem solving and learning of complex cognitive procedures is the Tower of Hanoi Puzzle (TOHP). In this task, participants are given a puzzle comprising three pegs and a stack of three to five differently sized disks (which determines the difficulty level) placed on one peg forming a conical shape. Participants are asked to replicate this conical stack on another peg while following a set of simple rules restricting the movement of disks from peg to peg (e.g., disks can be placed only on top of larger disks and moving one disk at a time). Successful performance of the TOHP thus requires a range of executive functioning abilities including planning skills, visual imagery or mental modeling, abstract thinking, working memory, self-monitoring, and self-correction skills. TOHP has been widely used as a single-time task to assess executive functioning abilities such as planning and problem solving as well as implicit learning (Guevara, Martinez, Aguirre, & Ganzales, 2012; Huizinga, 2006; Miller & Cohen, 2001; Ward & Allport, 1997; Zelazo, Muller, Frye, & Marcovitch, 2003). Planning a solution for the TOHP involves envisioning a course leading from the task's initial condition to the end goal, which includes a series of middle stages or sub-goals. These stages or goals are operated following an accurate mental representation of the key features of the problem or an internal depiction or recreation of the problem in working memory during problem solving (Alibali, Phillips, & Fischer, 2009). Specifically, solving the task requires sub-goal management, which refers to the process of recursively thinking ahead about the future consequence of each intermediate action. In addition, counter-intuitive moves—intermediate steps in the opposite direction from the target goal—were also found to play an important role in TOHP performance (Klahr, 1994). As intermediate goals are achieved, the targeted representation must be adjusted until obtaining the end goal (Karat, 1982).

The effect of age on cognitive skill learning is unclear. In our opinion a distinction should be made between administering the TOHP once and several times. When the TOHP was used as a single-time task to assess executive functions, performance was shown to develop with age, in line with children's increasing ability to control thoughts and actions as they grow older (Flavell, 1971; Siegler, 1983). This view is in accord with neuropsychological research that correlated TOHP performance with prefrontal lobe function and dysfunction (Lezak et al., 2004). In addition, the maturation of these brain regions seems to be parallel to the appearance of Piaget's stages of cognitive development (Fuster, 1997; Glosser & Goodglass, 1990; Goldstein & Green, 1995; Lezak et al., 2004).

The protracted course of cognitive development begins in early childhood around age 4, although problem solving efficiency has been shown to be still immature (Borys, Spitz, & Dorans, 1982; Bull, Espy, & Senn, 2004; Klahr & Robinson, 1981; Welsh, 1991). Better performance is seen in ages 7–8. However, successful performance of the task is most often achieved at ages 11–13 years (Ahonniska, Ahonen, Aro, Tolvanen, & Lyytinen, 2000; Bishop, Aamodt-Leaper, Creswell, McGurk, & Skuse, 2001; Borys et al., 1982; Spitz, Minsky, & Bessellieu, 1985; Spitz, Webster, & Borys, 1982), reflecting shorter planning time and fewer moves needed to complete the task.

### 1.3. TOH and skill learning

To the best of our knowledge, only one exploratory study attempted to examine the development of cognitive skill learning using the TOHP (Beaunieux et al., 2006). In this study the researchers administered the task to adults in four sessions of 10 trials separated by one day. Findings confirmed the existence of three phases during cognitive skill learning (cognitive, associative, and automated), showing that skill learning did indeed take place (in terms of both moves and time) and that it changed across the learning sessions.). However, this study did not examine the additional improvements that may occur during offline learning or transfer. Offline learning refers to the additional behavioral improvements that take place in the absence of any further rehearsal or experience (Javadi, Walsh, & Lewis, 2011). Offline learning occurs after a period of nighttime sleep, although additional enhancement may occur after several days. It appears that offline learning depends on participants' initial amount of practice before the offline period and that greater initial practice leads to better offline enhancement (Hauptmann, Reinhart, Brandt, & Karni, 2005).

Transfer—the application of knowledge acquired in one situation or context to another—is an additional skill learning benefit that is integral to solving problems in everyday, real-world situations (Wedman, Wedman, & Folger, 1999). When encountering a new task with a solution structure resembling a previous task, individuals are able to apply principles from the mental scheme acquired in the original learning setting to the new context, despite the new task's distinct features (Catrambone & Holyoak, 1989; Chen, 1999). Knowledge is said to be transferred when performance on the second task is similar to or better than baseline performance on the initial task (e.g., Gomez, Gerken, & Schvaneveldt, 2000). However, the degree of transfer is largely determined by the level of similarity or overlap between the initial situation and the new context (Chen & Mo, 2004). The TOHP is particularly suitable for assessing transfer ability because it includes variant tasks ranging from lower to higher similarity, such as the highly similar task of moving the disks from the first peg to the third instead of vice versa (as used in the current study) or the less similar task of receiving the disks in an upside-down conical stack with the opposite rule for movement (e.g., disks can be placed only on top of smaller disks).

In addition, because transfer involves adapting knowledge, not just applying it (Schwartz, Chase, & Bransford, 2012), failure to transfer is often caused by a lack of deep initial learning (Chi & VanLehn, 2012). In other words, when learners do not acquire the problem schema during practice, and when they fail to notice the similarity between the examples and the subsequent novel task, their transfer abilities are limited (Chen, 1999). Thus, a sufficient number of trials to ensure initial schema acquisition is necessary to enable transfer to occur. Similarly to Beaunieux et al. (2006) the participants in our study were given 10 trials in the first session, so that they would be able to leave the cognitive phase by the end of the first session before they are given an interval of 24 h preceding the offline learning and transfer.

### 1.4. The current study objectives

In line with previous research showing that single-time performance of the TOHP task (indicating executive functions) was mastered at ages 11–13 years, the current study examined cognitive skill learning in two groups—in childhood (third graders) and in early adolescence (sixth graders)—to trace the developmental transition to skill acquisition. The current study also extended knowledge on the potential long-term effects of skill learning by examining the cognitive skill

Download English Version:

https://daneshyari.com/en/article/364553

Download Persian Version:

https://daneshyari.com/article/364553

Daneshyari.com