Available online at www.sciencedirect.com
ScienceDirect
Journal of Experimental Child Psychology 101 (2008) 20–51
Journal of Experimental Child Psychology
www.elsevier.com/locate/jecp

Costs and benefits of representational change: Effects of context on age and sex differences in symbolic magnitude estimation

Clarissa A. Thompson *, John E. Opfer

Department of Psychology, The Ohio State University, Columbus, OH 43206, USA

Received 3 December 2007; revised 12 February 2008
Available online 1 April 2008

Abstract

Studies have reported high correlations in accuracy across estimation contexts, robust transfer of estimation training to novel numerical contexts, and adults drawing mistaken analogies between numerical and fractional values. We hypothesized that these disparate findings may reflect the benefits and costs of learning linear representations of numerical magnitude. Specifically, children learn that their default logarithmic representations are inappropriate for many numerical tasks, leading them to adopt more appropriate linear representations despite linear representations being inappropriate for estimating fractional magnitude. In Experiment 1, this hypothesis accurately predicted a developmental shift from logarithmic to linear estimates of numerical magnitude and a negative correlation between accuracy of numerical and fractional magnitude estimates ($r = -.80$). In Experiment 2, training that improved numerical estimates also led to poorer fractional magnitude estimates. Finally, both before and after training that eliminated age differences in estimation accuracy, complementary sex differences were observed across the two estimation contexts.

Keywords: Conceptual development; Microgenetic; Transfer of learning; Sex differences; Number concepts; Magnitude estimation; Mathematical cognition; Representation

* Corresponding author. Fax: +1 614 688 8261.
E-mail addresses: thompson.1345@osu.edu (C.A. Thompson), opfer.7@osu.edu (J.E. Opfer).

0022-0965/$ - see front matter
doi:10.1016/j.jecp.2008.02.003

Introduction

Whether transferring knowledge from one classroom to another classroom, from early in the school year to later in the school year, or from one example to other similar examples, conceptual representations allow learners to generalize over situations that differ merely in place, time, and superficial details (Murphy, 2002). These examples of narrow transfer of learning are unremarkable and easy for learners to achieve because narrow transfer of learning apparently occurs automatically—that is, without learners consciously monitoring the breadth of their generalizations—as learners convert stimulus-specific verbal and visual information into abstract conceptual representations (Kourtzi & Kanwisher, 2001; Naccache & Dehaene, 2001; Potter & Faulconer, 1975; Potter & Kroll, 1987; Potter, Kroll, Yachzel, Carpenter, & Sherman, 1986). In this study, we examined one interesting implication of this analysis: Because narrow transfer is an *automatic* effect of abstract representation, representational changes can impose *costs* as well as benefits, leading to unavoidable setbacks in the course of learning that can persist for many years and across many contexts.

Evidence for the benefits of representational change is widespread in the literature. For example, when children are given corrective feedback on where to place a few numbers on a line flanked by 0 and 1000 and no numbers in between (number line estimation), accuracy improves greatly for numbers in the initial training set, learning transfers to numbers outside of the training set, and there is robust transfer of learning to related numerical tasks (e.g., categorizing numbers as "small" or "large"), with magnitude estimates on the transfer task being nearly identical to estimates on the training task (Opfer & Siegler, 2007; Opfer & Thompson, 2008). Moreover, real-world tasks that involve similar kinds of experiences (e.g., playing board games) also result in transfer to educationally important outcomes such as preschoolers' ability to compare numerical value and perform arithmetic (Griffin, Case, & Siegler, 1994; Ramani & Siegler, in press; Siegler & Ramani, in press).

Evidence for the costs of narrow transfer, however, is rare and indirect. One type of evidence for the costs of narrow transfer comes from research on cognitive illusions in adults (Kahneman & Tversky, 1996), who make grossly mistaken comparisons of risk when framed in a manner that invites inappropriate transfer of numerical representations. As a real-life example, genetic counselors often attempt to simplify the risks reported in epidemiological studies by reporting rates of disease in terms of simple frequencies (e.g., 1 in 333) rather than in scientific format, which reports rates of disease per unit of population exposed to the risk (e.g., 3 per 1000 persons) (Burkell, 2004; Grimes & Snively, 1999; Walker, 1997). Although this simplification is well meaning, research on patients' understanding of medical risks has shown that the simplification has the unfortunate consequence of leading patients to make inaccurate comparisons, for example, judging a disease with a rate of 1 in 384 persons as being higher than a disease with a rate of 1 in 112 persons (Grimes & Snively, 1999). Unlike the beneficial effects of transferring from the spacing of numbers in board games to the spacing of numbers on number lines, transferring from the number line to assessments of risk is costly in this case because, unlike the linear increase in spacing of numbers on number lines, the average risk of disease per unit of population (e.g., 1, .01, or .001 cases per person) increases as a power function of the population base in the simplified frequencies (e.g., 1 in 1, 1 in 100, or 1 in 1000).