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Working memory as a moderator of training and transfer of analogical reasoning in children

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ABSTRACT

Working memory is related to children's ability to solve analogies and other inductive reasoning tasks. The aim of this study was to examine whether working memory also plays a role in training and transfer effects of inductive reasoning in the context of a short training procedure within a pretest-training-posttest-transfer design. Participants were 64 children, aged 7–8 years (M = 7.6 years; SD = 4.7 months). All of the children were pre-tested on inductive reasoning and working memory tasks. The children were trained in figural analogy solving according to either the graduated prompts method or practice without feedback. The children were then post-tested on the trained task and three additional inductive reasoning measures. Regression models revealed that visuo-spatial working memory was related to initial performance on each of the inductive reasoning tasks ($r \approx .35$). Children's improvement from pretest to posttest in figural analogy solving, as measured with item response theory models, was somewhat related to visuo-spatial WM but not verbal WM scores or pretest scores. Furthermore, transfer of reasoning skills to an analogy construction task was related to initial ability, but not working memory; transfer to two inductive reasoning tasks with dissimilar content was not apparent. Performance change and ability to transfer trained skills to new tasks are not often used in psycho-educational assessment but may be separate constructs indicative of children's learning and change.

1. Introduction

Many studies have demonstrated a strong relationship between working memory (WM) and inductive reasoning ability in adults (e.g., Buehner, Krumm, & Pick, 2005; Kyllonen & Christal, 1990) as well as children (e.g., Alloway, Gathercole, Willis, & Adams, 2004; Tillman, Nyberg, & Bohlin, 2008). Generally these studies focus on the role of working memory on inductive reasoning performance in a single testing session. However, working memory may influence how well a person profits from instruction in solving reasoning tasks. For example, working memory may become more efficient due to training and this automation of skills may affect training and transfer effects (e.g., Dahlin, Neely, Larsson, Bäckmann, & Nyberg, 2008; Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Klingberg, Forssberg, & Westerberg, 2002). It is therefore plausible that working memory plays a role in children's learning and change in inductive reasoning. In the present study we apply dynamic testing principles to train and assess children's progression in inductive reasoning and examine whether working memory moderates training and transfer effects.

1.1. Dynamic testing of inductive reasoning

Dynamic testing diverges from traditional, static assessment methods in that feedback is provided by the examiner in order to facilitate learning and gain insight into learning efficiency (Elliott, Grigorenko, & Resing, 2010). In principle, dynamic testing formats do not differ from cognitive training formats, although cognitive training is often geared towards more extensive interventions. In dynamic testing, various indices are used to examine learning, such as performance improvement following feedback interventions (e.g., Hessels, 2009), the amount and type of instruction that best aides task solution (e.g., Bosma & Resing, 2012; Resing & Elliott, 2011), and the ability to transfer these newly developed skills to other problems (Campione & Brown, 1987). The current study uses a simple test-intervention-test format and aims to investigate children's progression and transfer in the domain of inductive reasoning. The intervention principles we used come forth from dynamic testing research, more specifically the graduated prompts approach (e.g., Campione & Brown, 1987; Resing, 1993).

Inductive reasoning tasks are quite frequently used in cognitive testing and training studies (e.g., Ferrara, Brown, & Campione, 1986; Resing, Tunteler, De Jong, & Bosma, 2009), because they are considered central to intelligence (Carpenter, Just, & Shell, 1990; Carroll, 1993). Classical analogies (A:B::C:?) and figural matrices (see Fig. 1) are often included as measures of cognitive

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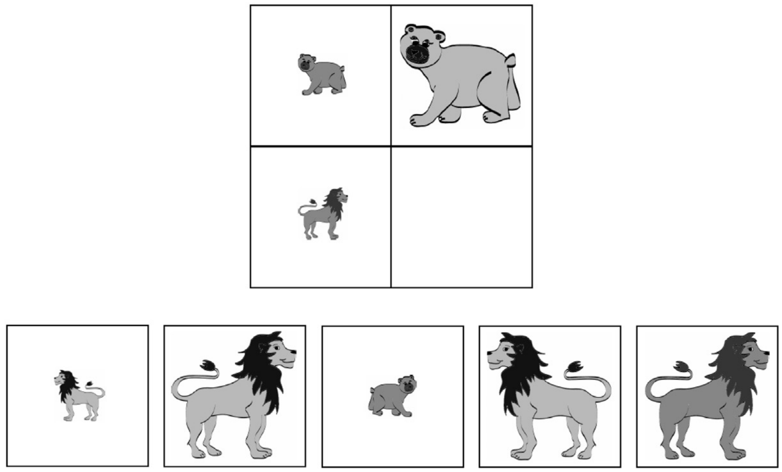

Fig. 1. A multiple-choice figural analogy item from AnimaLogica.

ability (Freund & Holling, 2011; Primi, 2001). Analogical reasoning, a form of inductive reasoning, is deemed essential to school learning and refers to the capacity to learn about a new situation by relating it to a structurally similar more familiar one (e.g., Goswami, 1992). The ability to reason by analogy is assumed to develop with great variability throughout childhood (e.g., Leech, Mareschal, & Cooper, 2008; Siegler & Svetina, 2002). Older children tend to perform better than younger children, which may be explained by improvements in efficiency of working memory capacity (Fry & Hale, 2000; Kail, 2007). Improvement in analogical reasoning can take place spontaneously with practice (e.g., Tunteler & Resing, 2002), with further learning effects provided by feedback (Cheshire, Ball, & Lewis, 2005), self-explanation (Siegler & Svetina, 2002; Stevenson, Resing, & Froma, 2009) and other training formats (e.g., Alexander, Willson, White, & Fuqua, 1987; Klauer & Phye, 2008). Training with graduated prompting techniques, a specific form of intervention used in dynamic tests, has been shown more effective than practice alone with regard to both learning and transfer (Bosma & Resing, 2006; Ferrara et al., 1986).

1.2. Transfer of inductive reasoning skills

The ability to spontaneously generalize a problem-solving approach taught in one context to a different but applicable situation is referred to as transfer. This is considered an important aim of formal schooling (e.g., De Corte, 2003). Basically, each form of transfer requires noticing an analogy or similarity between two more or less similar problems (e.g., Holyoak, 1984). However, numerous studies have shown that transfer does not occur easily as learning is context-bound and children rarely recognize that their acquired problem solving skills can be applied in novel situations (e.g., Barnett & Ceci, 2002; Bransford & Schwartz, 1999; Detterman, 1993; Siegler, 2006). According to Holyoak (1984) the process of finding an analogy between the base (trained task) and the target problem (transfer task) will end unsuccessfully "if the problem solver fails to encode elements of the schema, in either the base or the target " [problem], (Holyoak, 1984, p. 218). The use of base and target problems related to (the development of) analogical reasoning is mostly studied in the context of solving problem analogies (e.g., Gentner & Holyoak, 1997; Holyoak & Nisbett, 1988), but the processing steps for solving problem analogy versus classical analogy paradigms are equivalent: base and target problems (i.e. training versus transfer tasks) must have been mastered, features of both tasks have to be encoded, the potential relationship must be noticed, relationships of relevant task aspects must be mapped, and in this whole process inference and retrieval processes play an essential role (e.g. Gentner & Holyoak, 1997: Chen, 1995; Tunteler & Resing, 2004).

Jacobs and Vandeventer (1971) discerned near, far, and very far transfer, depending on the surface similarity of base and target task. Resing (1993) and Roth-van der Werf, Resing, and Slenders (2002) systematically assessed whether children trained in solving inductive reasoning tasks were able to generalize the taught problem solving skills to superficially similar and dissimilar problems measuring the same inductive reasoning skills. In their studies, trained children improved more on superficially similar tasks than those who only practiced with the same items. Progression on superficially dissimilar tasks, however, could be attributed to practice effects. Children may show greater transfer of knowledge when the targeted strategy has been mastered (Siegler, 2006). For example, Tunteler and Resing (2010) found that 8-year-olds who obtained high scores on a geometric analogy task improved more on a verbal analogies near-transfer task during the posttest than children with lower geometric analogy scores while using a microgenetic design with a training versus a repeated practice condition. Also in this study, progression in scores on the superficially dissimilar verbal analogy task was independent of having received training – practice alone appeared to elicit transfer in high ability children. Aside from practice effects, instructional conditions also appear to play a role in near-transfer. For example, Harpaz-Itay, Kaniel, and Ben-Amram (2006) found that 12-year-olds trained in verbal analogy solving also improved on geometric and numerical analogies, however, the transfer effects were greater in children trained in an analogy construction task as opposed to multiple-choice solution.

In this study we investigated the transfer of trained analogical reasoning to three related inductive reasoning tasks differing in superficial similarity, in content similarity, or in both content and superficial similarity. First, the geometric analogies task used by Tunteler and Resing (2010) was chosen as it differed in superficial structure from the figural analogies on which children were trained, but the deeper solving pattern (classical analogy) remains the same. Second, an analogy construction task (e.g., Harpaz-Itay et al., 2006) in a form for younger children where roles of examiner and child are reversed (Bosma & Resing, 2006) was administered, which differed in both surface structure and content, although