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Dynamic testing and transfer: An examination of children's problem-solving strategies

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A B S T R A C T

This study examined the problem-solving behaviour of 104 children (aged 7–8 years) when tackling construction-analogy tasks. Children were allocated to one of two conditions: either a form of unguided practice alone or this in combination with training based on graduated prompt techniques. Children's ability to solve figural open-ended analogy-problems was investigated as well as their ability to construct new analogy problems themselves. We examined children's progression in solving analogy problems and the variability in their strategy-use. Results showed that the group that received training made greater progress in solving analogy problems than children who only received unguided practice opportunities. However, the training appeared to give no additional improvement in performance on the transfer task over that of repeated unguided practice alone. Findings from this study demonstrate that an open construction task can provide additional information about children's cognitive learning potential.

1. Introduction

In education, teaching new concepts, knowledge, and problem-solving strategies is common practice. A core aim of teaching is transfer of learning to new situations and contexts. The ability to generalize that what has been learned to new, related tasks, however has been and still is a major challenge (Bransford & Schwartz, 1999; Day & Goldstone, 2012; De Corte, 2003), and has been subject of research for more than a century (Engle, 2012; Larsen-Freeman, 2013). According to Holyoak (1984), transfer requires individuals to perceive the underlying relationship between two problems with some level of similarity (see also Brown, 1982; Brown, Bransford, Ferrara, & Campione, 1983). This is often difficult to accomplish, particularly for young children, and many cognitive training studies since then have shown that children do not easily generalize newly learned strategies to other problems and contexts (e.g. Detterman, 1993; Opfer & Thompson, 2008). Holyoak described transfer as the process of finding an analogy between a base (trained task) and a target problem (transfer task). This process 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), or if a taught strategy becomes "welded" to a specific task (Brown, 1978). Furthermore, the use of taught knowledge or problem-solving strategies is often restricted to near transfer and limited to (very) familiar contexts and purposes (e.g., Detterman, 1993).

Siegler (2006) noted that children will only show transfer of knowledge to novel tasks once they have become good strategic solvers, although this is, according to him, likely to be preceded by variable strategic behaviour (see also Perry, Samuelson, Malloy, & Schiffer, 2010). With reference to dimensions such as content and context (Barnett & Ceci, 2002), researchers have differentiated, among others, between surface versus deep transfer (Forbus, Gentner, & Law, 1995), formal versus material transfer (Klauer, 1998), and near versus far transfer (Jacobs & Vandeventer, 1971). Transfer has been found to occur consciously and unconsciously (Day & Gentner, 2007; Day & Goldstone, 2012), instantaneously and very gradually, and after task mastery (Siegler, 2006), or after more variable strategic behaviour (Perry et al., 2010).

Variability in performance and strategy-use on one or more tasks occurs both over the course of development and across cognitive domains. This has been demonstrated by several studies regarding the range of cognitive strategic behaviours that children show when solving scholastic tasks (e.g. Bjorklund & Rosenblum, 2001; Chen & Siegler, 2000; Siegler, 2007; Tunteler & Resing, 2002, 2010). Therefore, when measuring children's cognitive abilities and potential to generalize learned knowledge and solving procedures to new, related tasks, it would be interesting to take into account children's progression as well as fluctuations in their use of problem-solving strategies when tackling tasks.

Inductive reasoning tasks, such as classification, analogies, or series completion, are often used in the measurement of cognitive

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development and transfer. The ability to reason by analogy, for instance, is even thought to be closely related or even identical to the underlying transfer process (Alexander & Murphy, 1999; Reeves & Weisberg, 1993). Inductive reasoning tasks all require comparable underlying problem-solving processes: starting with specific observations of the provided information, a rule that leads to the solution must be detected and formulated. This rule finding process is achieved through comparison processes (Holyoak & Nisbett, 1988; Pellegrino & Glaser, 1982; Perret, 2015). Klauer (1992, 2014) stated that all inductive tasks can be solved by means of systematic comparison processes, which involve finding similarities and/or differences between task attributes and/or relations among attributes. Inductive reasoning undoubtedly plays an important role in (classroom) learning processes as well as in transfer, as these often also require the ability to detect regularities in seemingly non-ordered material and rules for task solving (e.g. Csapó, 1997; Csapó, Molnár, & Nagy, 2014; Goswami, 1992; Klauer & Phye, 2008; Morrison et al., 2004; Perret, 2015; Vosniadou, 1989). Close inspection of children's inductive reasoning abilities, including the influence of training on the use of more advanced solving strategies (e.g. Higgins, 2015), is complex as a consequence of the variability in performance over time, as sketched above. Transfer of analogical reasoning skills to new tasks or contexts is also difficult to detect, because children show individual differences in the development of their strategy-use over time (Siegler, 2006).

The current study sought to examine children's strategic behaviour when tackling different types of construction-analogy tasks: those tasks presented to them and which they had to complete, and others where they were asked to construct new problems themselves. Children received either a form of unguided practice alone or this in combination with training. By these means, we compared the effects of two different treatments on children's solving of tasks requiring analogical reasoning and on their ability to generalize knowledge and procedures derived from (one of) these treatments to new tasks. The main focus of our study was therefore on 'the breadth of change' dimension of Siegler's (1996) 'overlapping waves' theory. This theory refers to the range of change, variability, generalization or transfer of previous learning to other problems and contexts.

Our study differed from most other studies on transfer because a 'reversal' procedure was employed. As mentioned, in addition to opportunities to practice, some of the children received a training session geared towards helping them to solve open-ended figural analogy problems. Subsequently, the children were also invited to take a more active role by constructing new problems of the kind they had been given before, which the examiner was then required to solve (Bosma & Resing, 2006; Kohnstamm, 2014).

To encourage transfer of previously learned or practiced problem-solving strategies, the surface features of our reversal (self)construction task were kept the same as those of the open-ended figural analogies tasks children had to tackle during the practice and training sessions. During these sessions, children had to construct and subsequently explain their answers. We assumed that the use of the same matrix-format and testing materials would prime the children to draw upon their previous experiences and learning (Day & Goldstone, 2012). This permitted the construction of comparable/equivalent figural analogies as were administered in the tasks used during the previous sessions. Nevertheless, these surface similarities do not necessarily make the process of transfer straightforward. The reversal (self)construction format was assumed to be much more challenging than the open-ended figural analogies task, since it was assumed that the former required children to extract analogical strategies from their own idiosyncratic schemas in their memory in order to construct the analogies. Such complexity would not be required for the tasks with the "normal" open-ended construction format (Martinez, 1999). Our transfer task was assumed to balance between the "high road" and "low road" transfer mechanisms discerned by Salomon and Perkins (1998). According to them, high-road transfer occurs through intentional mindful abstraction of elements from a certain context including their application to a new context. The elements abstracted during this process often have the form of a rule or scheme. Low-road-transfer can only lead to a narrow range of transfer and is based on extensive and varied practice and occurs as a consequence of automatic activation of previously learned behaviour in a new situation.

Providing children with the opportunity to move beyond practice experiences to engagement in problem construction may not only shed light on children's abilities to transfer learning but also on individual differences in the developing use of problem-solving strategies (Haglund & Jeppsson, 2012; Kim, Bae, Nho, & Lee, 2011; Pittman, 1999; Siegler, 2006). Therefore, the problem construction task utilised in the current study was administered to assess the extent to which children's learning on the initial task subsequently transferred to one that involved a reversal of roles. However, to achieve this, an in-depth understanding of children's growth trajectories would be useful. Here, the use of a microgenetic research design may prove especially helpful (Siegler, 2006; Siegler & Svetina, 2002; Tunteler & Resing, 2007; Winne & Nesbit, 2010). Such measurement designs, including regular measurements of an individual's changing performance on a number of parallel tasks over a relatively short period of time (Siegler & Crowley, 1991), were developed to investigate both the spontaneous development of cognitive abilities and a child's learning progress. In the current study, we combined both dynamic testing and a microgenetic method of studying children's development and learning. We investigated whether children's growth trajectories showed differing pathways of transfer when acquired through more 'natural' unguided practice opportunities than when a short training procedure, as part of a dynamic test, was included.

Dynamic testing, using a test-training-test format, has become increasingly used for the study of inductive reasoning (e.g. Bethge, Carlson, & Wiedl, 1982; Budoff, 1987; Ferrara, Brown, & Campione, 1986; Resing, 1993; Resing & Elliott, 2011; Tzuriel, 2013). Key to this approach is the incorporation of feedback and training during the testing phases (Elliott, Grigorenko, & Resing, 2010; Grigorenko & Sternberg, 1998: Haywood & Lidz, 2007). Unlike conventional forms of static testing, where usually no feedback on how to improve performance is given, dynamic testing aims to investigate children's progression in performance after they have been given explicit, sometimes tailored, assistance during test session(s). Such a testing procedure may provide important information about children's potential for learning (Grigorenko, 2009; Jeltova et al., 2011; Resing, 2013). In fact, a (dynamic) training procedure combined with a microgenetic research method has been found to yield significant differential inter- and intra-individual learning trajectories after both repeated practice, and training experiences (Resing, 2013; Resing, Tunteler, & Elliott, 2015; Tunteler, Pronk, & Resing, 2008). In the current study, we used a training procedure derived from dynamic testing to examine whether training and practice, versus practice alone, resulted in different growth trajectories in children's analogical reasoning and ability to transfer the learned or practiced solving strategies to a new, but strongly related, (self)construction task.

To aid our analysis, we included children's explanations immediately gathered after administering each analogy problem (Church, 1999; Siegler & Stern, 1998). For children aged five years and older, the literature has shown the benefit of combining observations of behavioural solution strategies with their immediate descriptions of how they sought to solve the problem. The value of this approach has been shown in studies in various domains, such as arithmetic (Siegler & Stern, 1998), reading (Farrington-Flint, Coyne, Stiller, & Heath, 2008), and inductive reasoning (Resing, Xenidou-Dervou, Steijn, & Elliott, 2012; Stevenson, Hickendorff, Resing, Heiser, & de Boeck, 2013).

In the current study, an innovative way of measuring transfer was used, derived from Kohnstamm's (1968, 2014) procedure for testing young children's ability to solve seriation/class inclusion tasks. The study examined whether children were able to construct transfer