Learning trajectories in analogical reasoning : exploring individual differences in children's strategy paths

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CHAPTER 5

What can an analogical construction task reveal about changes in children's problem-solving strategy?

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Abstract

In this study, improvements in children's analogical performance were assessed, by asking them to construct analogies rather than solve them, as is traditionally the case. Quantitative and qualitative inter- and intra-individual measures were investigated. After holding important background variables (working-memory and initial capacity) constant, results showed that those children, who had made most progress in utilizing and explaining analogical strategies when solving classical analogies, demonstrated similar strengths when asked to construct analogies. It was also shown that the dynamic training resulted in improved capacity on the par of the children to reflect upon the strategies employed. Therefore, adding an analogical construction (transfer) task to dynamic-test-situations could provide additional important information about young children's inter- and intra-individual changes in analogical performance.

5.1 Introduction

The development of inductive (particularly analogical) reasoning in children has been extensively described elsewhere (Goswami, 1992; Morrison et al., 2004), especially its role in cognitive development (Goswami, 2002) and classroom learning (Csapó, 1997; Vosniadou, 1989). The first years of primary school are a time for rapid intellectual development and, unsurprisingly, this results in the variable use of inter- and intra-individual cognitive strategies (e.g., Siegler & Svetina, 2002). In order to gain insight into such processes, analogical tasks, sometimes incorporating dynamic testing procedures (Grigorenko, 2009), have been employed for differentiating and, potentially, predicting children's cognitive development and future educational progress. However, to achieve this, in-depth understanding of children's developmental trajectories is required. Here, the use of a microgenetic research design may prove especially helpful (Siegler & Svetina 2002; Tunteler & Resing, 2007).

Microgenetic research & dynamic testing

Microgenetic research designs involve the detailed study of children at times when they are likely to display rapid developmental growth. To achieve a fine-grained picture, these designs utilize frequent sampling of performance over a relatively short time period. Observation of children's responses, when given repeated practice experiences, enables researchers to identify changes in reasoning strategies and differential developmental trajectories as they happen. Development is considered to occur naturally, as, by design, the practice sessions include no explicit forms of intervention (Flynn & Siegler, 2007; Siegler & Crowley, 1991).

In contrast with traditional forms of assessment, dynamic approaches seek to ascertain what children can achieve when they are provided with tailored assistance during the testing procedure. In line with Vygotskian theory, such a procedure may add important information about children's potential, should they be given an appropriate educational program (Grigorenko, 2009; Resing & Elliott, 2011; Swanson & Lussier, 2001). In fact, a (dynamic) training procedure combined with a microgenetic research design has been found to yield significant differential inter- and intra-individual learning trajectories after both repeated practice, and training experiences (Pronk, Elliott, de Rooij & Resing, submitted; Resing, 2013; Tunteler, Pronk, & Resing, 2008). However, it is unclear whether an analogical construction task, deemed in this case to be an example of transfer of learning, can offer additional and valuable information. It is the exploration of this issue that is reported in the present paper.

Breadth of change (transfer)

According to Siegler's (1996) overlapping waves theory, cognitive change is meaningfully described along five dimensions of change: the source, path, rate, variability and breadth of change. The theory co-evolved alongside the microgenetic research approach as a means to interpret observed developmental processes of variability, choice, and change. The focus of the current study was 'the breadth of change' dimension, which refers to generalization, or transfer, of previous learning to other problems and contexts.

Transfer of learning has been the subject of research for more than a century (Larsen-Freeman, 2013; Engle, 2012). With reference to dimensions such as content and context (Barnett & Ceci, 2002), researchers have differentiated between surface versus deep transfer (Forbus, Gentner, & Law, 1995), formal versus material transfer (Klauer, 1998), and near versus far transfer. Transfer has been found to occur consciously and unconsciously (Day & Goldstone, 2012; Day & Gentner, 2007), instantaneously and very gradually (Siegler, 2006), after task mastery (Siegler, 2006), or after more variable strategic behavior (Perry, Samuelson, Malloy, & Schiffer, 2010).

Transfer of strategies to construction tasks

We attempted to examine differences in children's learning by using an analogical construction (transfer) task after they had earlier received a number of practice opportunities and a dynamic-test-type training procedure geared to help them solve such problems. For this subsequent study, children were not required to solve analogies in the traditional fashion, but instead, were asked to take a more active role by constructing similar problems for the examiner to solve (Bosma & Resing, 2006). To encourage transfer of previously learned strategies, the surface features of the task were the same as those of the classical analogical tasks that had been tackled earlier during the practice and training sessions. We primed the children to draw upon previous learning (Day & Goldstone, 2012) by using the same matrix-format and the same animal cards, which permitted the same types of transformation. Nevertheless, these surface similarities did not necessarily make the process of transfer straightforward. The construction format was more challenging than the open-ended classical version, since the former required children to extract analogical strategies from schemas in their memory in order to construct the transformations. Such complexity was not required when tackling the classical format (Martinez, 1999). Effective constructors in our sample were therefore assumed to have gained a more thorough or 'deeper' understanding of the underlying principles of the analogical tasks (Harpaz-Itay et al., 2006; Perkins, 1992). It would appear that patterns in strategy use might differ when constructed response tasks (Stevenson, 2012), or construction tasks (Harpaz-Itay et al., 2006) are employed rather than multiple-choice tasks (Stanger-Hall, 2012).

Some patterns in strategy use in young children's performance on figural analogies have already emerged. Siegler & Svetina (2002), for example, found that when children were given analogical tasks with a multiple-choice format, the most common error was the selection of a duplicate of one of the matrix cells.

Providing children with the opportunity to move beyond practice experiences to engagement in problem construction may shed light on individual differences in their developing use of strategic reasoning (Pittman, 1999; Kim, Bae, Nho, & Lee, 2011; Haglund & Jeppsson, 2012; Siegler, 2006). As such, the analogical construction task used in the current study served a twofold purpose. First, we sought to assess the extent to which children's learning in relation to performance on a traditional analogical task subsequently transferred to one that involved construction. Second, we examined the ways in which this may provide additional information, both qualitative and quantitative, that could be used within a dynamic assessment context (Grigorenko, 2009; Resing, 2013).

To aid our analysis, we made use of immediate retrospective self-reports (Siegler & Stern, 1998; Church, 1999; Bosma & Resing, 2006). For children aged five years and older, an increasing body of literature points to the strength of combining observations of behavioral solution strategies with immediate retrospective self-reports. The value of this approach has been found in studies of 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).

Initial ability and working memory

Two additional factors were included in this study: initial ability in task performance and working memory. These have been regarded as important indicators of future task performance that draws upon previously learned material (Day & Goldstone, 2012; Rittle-Johnson, Star, & Durkin, 2009). Working memory, which typically becomes more efficient with age (Siegler, 2006), is considered to be the workspace for the construction of relational representations (Halford, Wilson, & Philips, 2010). If processed in parallel, only a limited number of relations can be constructed at any one time (Halford, Wilson & Philips, 1998). However, complex relations can be recoded into representations of lower complexity, or be segmented into smaller parts, in order that these can be processed serially (Halford et al., 2010). More efficient execution of strategy use is therefore likely to reduce working-memory demands (Siegler, 2006).

Research aims and hypotheses

In this study, a transfer task requiring the construction of analogies was employed in order to examine children's progress in analogical performance. To achieve this, we utilized quantitative and qualitative, inter- and intra-individual measures.

1. A first set of hypotheses concerned the number of correct analogies that a child would be able to construct. We expected that this would be related to (1a) spatial working-memory (Halford et al., 2010; Rasmussen & Bisanz, 2005), and (1b) initial performance on traditional analogical tasks (Day & Goldstone, 2012). When holding these background variables constant, we did not expect to find a relationship between children's progress in the number of analogical tasks they correctly solved following (1c) repeated practice experiences or (1d) dynamic training, and the number of completely correct constructed analogies at the transfer session (e.g., Tunteler & Resing, 2010). We did, however, expect to detect transfer of learning in analogical strategy use by closely considering the processes involved. Thus, we examined the individual transformations within the solved and constructed analogies, and also the children's subsequent accounts of these.

2. A second set of hypotheses concerned the number of transformations that were constructed correctly at the transfer session. Again, our expectations were related to our background variables. It was anticipated that children's employment of transformations in their constructed analogies would be related to (2a) spatial working-memory (Halford et al, 2010; Rasmussen & Bisanz, 2005), and (2b) their employment of transformations during their first session with the conventional analogical tasks (Bosma & Resing, 2006). When holding these background variables constant, we expected to find a relationship between children's progress in analogical strategy use through (2c) repeated practice, (2d) dynamic training, and the number of transformations they employed during the transfer session.

3. A third set of hypotheses concerned children's reflections on their analogical strategy use. We expected that children would be able to discuss and explain a greater number of transformations at the transfer session, if their accounts were also (3a) superior at the first session with conventional analogies, and their performance had improved as a result of (3b) repeated practice experience and (3c) dynamic training (Tunteler et al., 2008).

4. Our fourth set of hypotheses concerned children's qualitative reports of non-analogical, and analogical strategy use. We hypothesized (4a) that both children in the dynamic training condition, and those who were more successful in producing correctly constructed analogies, would cite analogical strategy use or offer their 'own rules' for incorrectly constructed analogies. We hypothesized (4b) that children in the practice condition who were unable to

construct any correct analogies would either provide 'copy' or 'procedural' explanations, or tell stories about the animals involved in their constructions. Furthermore we hypothesized (4c) that the transformations that would be explained most frequently would involve color, size and number. We expected the transformations, 'orientation' and 'position', to be explained less frequently, as these are seemingly more difficult to explain (Siegler & Svetina, 2002).

5.2 Method

Participants

Participants[3] (N=104; 51 boys; 53 girls) were aged 7-8 years with a mean of 93.6 months (*SD* = 4.8 months). They were selected from the second grade of eight regular primary middle-class schools located in the Netherlands. Parental informed consent was obtained for each participant.

Design

In an earlier study involving this sample (Pronk et al., submitted), each child's inductive reasoning and working-memory capacity were assessed by means of an Exclusion test and a measure of spatial working-memory (see descriptions below). Subsequently, a microgenetic two-pretest-two-posttest control-group design was employed with randomized blocks based on the Exclusion test (see Table 1). After the fourth (final) session, both conditions received the same analogical construction task, which served to assess their breadth of cognitive change (transfer). It is this final stage that is the focus of this paper.

Table 1. Research design[1]

	Session						
Condition	Pretest	1	2	Training[2]	3	4	Transfer
Practice	x	x	x	-	x	x	x
DT	x	x	x	x	x	x	x

Note: [1]Sessions 1 to 4 were reported elsewhere (Pronk et al., submitted). The current study's focus was transfer of cognitive changes induced by this type of design. [2]The practice-condition received the same items as the training condition, but the practice-condition received no dynamic-test-type training.

Instruments

Exclusion

Exclusion is a visual inductive reasoning subtest of a Dutch child intelligence test (RAKIT: Revisie Amsterdamse Kinder Intelligentie Test (Bleichrodt, Drenth, Zaal, & Resing, 1984). The subtest consists of 40 items each comprising 4 geometric figures. Three of the figures can

3 Participants include all participants of Chapter 4.

be grouped together on the basis of a rule that needs to be identified. The task requires the child to select the figure that, in each case, does not fulfill the rule.

Spatial recall

The Spatial recall test from the computerized Automated Working Memory Assessment (AWMA) battery (Alloway, 2007) was used to measure visual spatial working-memory capacity. The task involves recalling the positions of dots in relation to arbitrary shapes that rotate and/or flip from left to right.

Figural analogies

The analogical reasoning task consisted of an age-adapted version of the concrete figural analogies measure developed by Stevenson and Resing (e.g., Stevenson, Resing, & Froma, 2009; Stevenson, Touw, & Resing, 2011). The four practice sessions included four parallel sets with 20 open-ended 2x2 figural matrix analogies. The figures consisted of various permutations of six types of animals with three familiar colors, and two sizes; features that would be easily recognized by the participating children (Goswami, 1992). Items contained up to six transformations, involving size, color, number, orientation, position, and animal. Other than in the training session, the examiner provided minimal instruction, and this was unrelated to solving the analogies. After the production of each solution, the child was asked how he or she had solved the 'puzzle'.

Figural analogies dynamic-test-type training

The dynamic-test-type training material (Pronk et al., submitted), consisted of an age-adapted set of seven concrete figural analogy problems similar to those employed in the other sessions (these were adapted from Stevenson et al., 2009; 2011), and operated in accordance with Resing's (e.g., 1993) graduated-prompts dynamic test format. This approach has been successfully utilized in several previous studies (e.g., Resing, 2000; Resing & Elliott, 2011; Resing, Tunteler, de Jong, & Bosma, 2009; Resing, Steijn, Xenidou-Dervou, Stevenson, & Elliott, 2011, Resing et al., 2012). It utilizes a series of adaptive and standardized, hierarchically ordered, metacognitive (self-regulating) and cognitive prompts that proceed from general to task-specific. The prompts are provided only if the child is unable to proceed independently. Prompts become increasingly explicit, until the child arrives at the solution.

Our procedure involved the presentation of more challenging items from the beginning. While seemingly counter to usual practice, this has proven to be a helpful means of enabling even the most able performers to benefit from training from the outset. As a result, all the children in the sample are equipped to draw upon their newly learned strategies when tackling easier items (e.g., Resing, 1993; Resing & Elliott, 2011).

Construction tasks

The first analogical construction task included an A4-sized sheet displaying an empty matrix with four cells and baskets with all 72 animal cards. They were informed that they would now be the teacher and the examiner would take on the role of the child. The child was shown the empty matrix and told that this was an 'empty puzzle' in which he or she was allowed to make a puzzle using any of the cards for the examiner to solve, just like the puzzles the examiner had provided earlier. In this way, the child was able to spontaneously display his or her understanding of the tasks he or she had solved thus far.

Prior to commencing the other construction tasks, the examiner filled one of the cells of the matrix (the B or C cell) and the child was given the exact cards needed to create the puzzle for the examiner to solve. While the first construction task left freedom for the child to use any number and type of the 72 cards, the child was now given a restricted set of cards, all of which she or he was required to utilize for constructing 'the puzzle'. The restricted set of cards provided for these tasks were such that in order to utilize all the given cards *and* construct a correct analogy, the transformations number, color, and size, (and animal for the 3rd task only) needed to be included. By their own insight, children could opt to make the constructed analogies even more complex by choosing to flip the cards and/or position to include the transformations 'position' and 'orientation'.

For each of the tasks, the children were given as little instruction as possible in order to maximize spontaneous strategic analogical behavior. Some children, however, failed to start the task or forgot to leave one of the cells of the analogy open for the examiner to complete. In such situations, the child was given up to a maximum of 3 hints. Assistance was only given to help the child construct something that had the appearance of an analogy (with three filled and one empty cell) that the examiner could be asked to solve (see Appendix A for the procedure). After the child had finished creating the puzzle, the examiner placed down some random animal cards and asked a) if this was the correct answer, b) what was the child's correct answer, and c) why that was the correct answer. All explanations that the children gave about their analogy, including those that were provided before the examiner had asked for their explanations, were included in the scoring process.

Scoring

Table 2 provides the scoring system for the analogical measurements.

Table 2 Scoring system analogical measures

Score Type	Progress over time (Predictor Variables)	Measurement level	Transfer (Outcome Variables)	Measurement level
Complete Analogies Correct	Percentage of analogies that were completely and correctly solved during session 4 minus their score on session 1.	Ratio Scale; Scores could potentially range between 0-20.	The sum of correctly constructed analogical tasks (analogical tasks that were constructed in three terms, that could yield a full analogy if the right solution was created in the fourth empty term).	Ordinal Scale; Scores could potentially range between 0-3.
Transformations Correct	Percentage of correct transformations as evidenced by the child's behavioral solutions during session 4 minus their score on session 1.	Ratio Scale; Scores could potentially range between 0-110.	The sum of the transformations present within the correctly constructed analogical tasks. Transformations present in both the row and the column of the constructed analogical tasks were counted and summed up.	Count Data
Explained Transformations Correct	Percentage of correct transformations that children explained about their solutions during session 4 minus their score on session 1.	Ratio Scale; Scores could potentially range between 0-110.	The sum of correct transformations that children explained about the solutions to the analogical tasks they constructed. Explanations of correct transformations of all constructed analogical tasks were counted, whether the analogical task was completely correct or not.	Count Data
Implicit & non-analogical strategies[1]	N/A	N/A	The sum of each category (see Appendix B) a child mentioned when they subsequently explained the solution to their analogy.	Interval Scale; Scores per category could potentially range between 0-3.

Note: [1] If a child did not explicitly mention one or more correct transformations when explaining their solution to an item (or construction in the case of the reversal task), their explanation was not regarded as 'explicit analogical', but instead was categorized into one of seven 'explanation' categories (see Appendix B).

Analyses

The first outcome variable (Table 2) was an ordinal variable, violating the assumptions of least-squares regression. For this reason ordinal logistic regression was performed. (Agresti, 2007). The second and third outcome measures were specified as counts (Table 2). An appropriate regression analysis for this class of data is Poisson regression, of which type we performed a negative binomial regression. (Agresti, 2007). All regression analyses were run with successive nested models that each included an additional expected variable. These nested models were compared with a likelihood ratio test to determine if the succeeding model – and therefore the added predictor – presented a significantly better fit than the previous one (Agresti, 2007). For each outcome measure we first included the background variables (working-memory and/or initial capacity) in the models, after which the variables of main interest were included: progress in analogical performance and condition.

For the qualitative analyses, the focus was on the strategies that children described when discussing how they solved each of their 'puzzles' (see Appendix B), and their accounts of the type and number of transformations at the transfer session.

5.3 Results

Before conducting the regression analyses, we checked for possible initial differences between the dynamic test and practice conditions. The mean scores on the Exclusion test did not differ significantly, nor did the mean number of complete analogical solutions, transformations or explanations at session one. Means and standard deviations for the analogical measurements utilized in this study are provided in Table 3.

Table 3. Means and standard deviations of analogical measurements

	Progress over time[1]	Transfer Session
Condition	Mean (SD)	Mean (SD)
	Correct Solutions	
Practice (N=52)	11.06 (15.16)	.67 (.88)
Dynamic Training (N=52)	22.60 (20.73)	.73 (.89)
Total (N=104)	16.83 (18.89)	.70 (.88)
	Transformations Correct	
Practice (N=52)	6.28 (11.88)	3.13 (4.53)
Dynamic Training (N=52)	18.36 (20.98)	3.60 (4.54)
Total (N=104)	12.32 (18.02)	3.37 (4.52)
	Explained Transformations	
Practice (N=52)	.81 (10.55)	1.44 (1.93)
Dynamic Training (N=52)	7.20 (15.69)	2.02 (2.42)
Total (N=104)	4.00 (13.68)	1.73 (2.20)

[1]Progress over time is given in percentages.

Regression analyses with likelihood ratio tests

To investigate our first set of hypotheses concerning the number of correctly constructed analogies at the transfer session (ranging 0-3), we performed ordinal logistic regression analyses with five successive models (including the intercept only model, see Table 4). The best fitting model – Model 3 in Table 4 – confirmed our expectations that children would construct more correct analogies at the transfer session if at the start of the study they demonstrated (1a) superior spatial working-memory (β=.02, p=.03), and (1b) a higher score for the analogical tasks (while holding spatial working-memory constant) (β=.05, p<.001). The final two models – Models 4 and 5 in Table 4 – did not prove to be a significant improvement to our first models. This confirmed our expectation that we would be unable to detect a relationship between progress in the number of correct solved analogical tasks following (1c) repeated practice experience (β=.02, p=.19), or (1d) dynamic training and the number of correctly constructed analogies at the transfer session (while holding spatial working-memory and initial performance constant) (β=-.03, p=.96).

Table 4. Results of the likelihood ratio tests for the nested models

Outcome measure of the transfer session	Model Progression[1]	Likelihood Ratio test		
		Likelihood Ratio[2]	*DLR*[3]	*P*
Analogies constructed completely correct[4]	1. Intercept only (Null)	0	-	-
	2. + Working Memory Spatial Span	19.94	19.94*	< .001
	3. + Initial Capacity[6]	**45.72**	**25.78***	**< .001**
	4. + Progress in analogical performance	47.56	1.85	.17
	5. + Condition[4]	47.57	.01	.92
Transformations present in complete analogies[5]	1. Intercept only (Null)	0	-	-
	2. + Working Memory Spatial Span	15.62	15.62*	< .001
	3. + Initial Capacity	75.14	59.52*	< .001
	4. + Progress in analogical performance[6]	**79.77**	**4.63***	**.03**
	5. + Condition[4]	79.79	.02	.89
Explained transformations[5]	1. Intercept only (Null)	0	-	-
	2. + Initial Capacity	18.52	18.52*	< .001
	3. + Progress in analogical performance[6]	**25.25**	**6.73***	**.009**
	4. + Condition	26.10	.85	.36

** Significantly better fit than former models at $p \leq .05$; [1]Each successive model included one additional predictor and the former model was nested within the succeeding model. [2]The likelihood ratio chi-square is the difference between the -2 log likelihoods of the intercept-only and the current model. [3]DLR is the difference in the Likelihood Ratio statistics of two nested models and is a statistical test for the variable that enters the model. [4]Ordinal regression with nested models compared with a likelihood ratio test. [5]Negative binomial regression compared with a likelihood ratio test. [6]Bold = this was the final model as the additional effect included in this model was the last one to further improve the model.*

To investigate our second set of hypotheses concerning the number of transformations included in the correctly constructed analogies (observed range: 0-17) at the transfer session, negative binomial regression analyses were utilized. Again, five successive models were run and compared to each other using a likelihood ratio test (see Table 4). Model 2 confirmed hypothesis 2a, concerning working-memory capacity. However, the best fitting model was Model 4, where working-memory no longer contributed significantly (β=.01, p=.22). Model 4 did confirm our expectations that children would use more transformations in their constructed analogies at the transfer session if they initially utilized more transformations at the first practice session (β=.05, p<.001) (hypothesis 2b). Model 4 also confirmed hypothesis

2c, which anticipated a positive relationship between children's progress in analogical strategy use through repeated practice experience over time, and the number of transformations these children used within their correctly constructed analogies at the transfer session (β=.02, p=.03) (again, while holding spatial working-memory and initial capacity constant). Model 5 (Table 4) included the condition variable, but unexpectedly this model was not a significant improvement upon the former model. This, therefore, failed to support hypothesis 2d, which anticipated a positive relationship between the dynamic-test-type training and the number of transformations children used within their correctly constructed analogies at the transfer session (while holding the former significant effects constant).

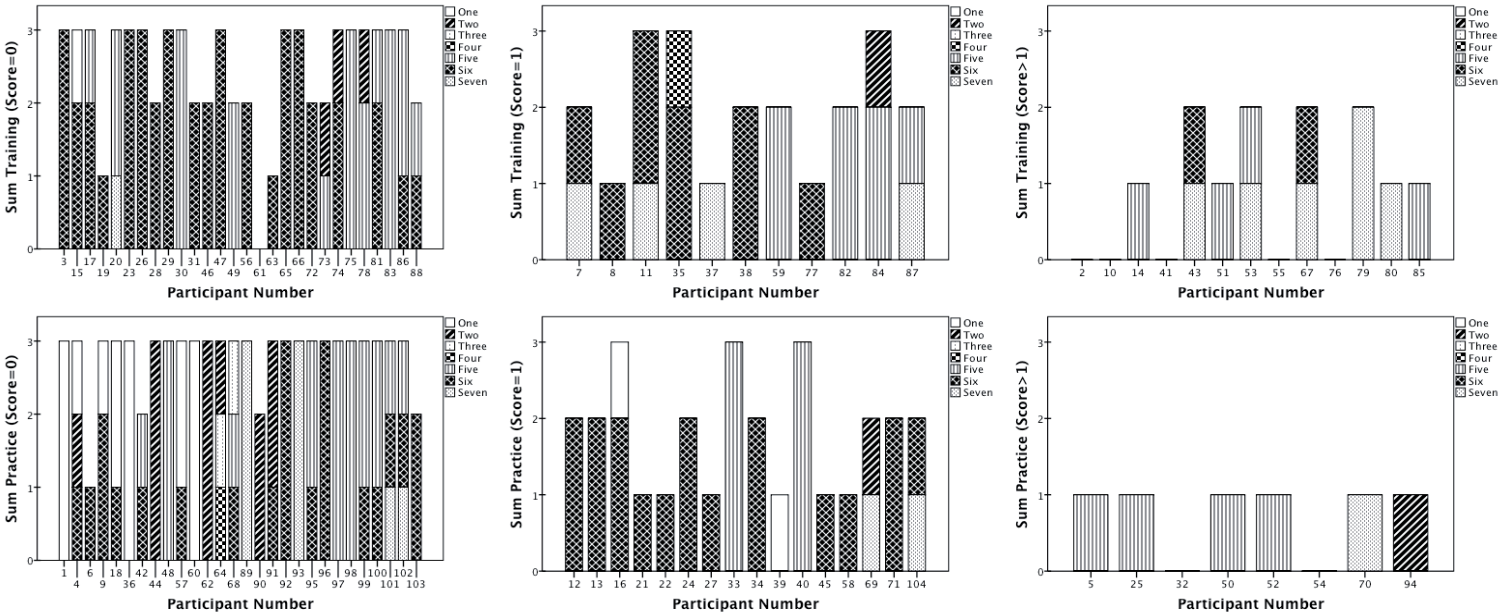
To investigate our third set of hypotheses concerning the number of transformations explained correctly after each construction task had been completed (observed range: 0-10), negative binomial regression analyses were utilized. Four successive models were run and compared with a likelihood ratio test (see Table 4). The best fitting model, Model 3, confirmed our expectations that children would provide explanations indicating superior analogical strategy use at the transfer session if they had performed well at the first session (β=.03, p<.001) (hypothesis 3a), and if they had made progress explaining analogical strategies during the practice sessions (β=.02, p=.01) (hypothesis 3b).

Model 4 (Table 4) included the condition variable, but unexpectedly this was not a significant improvement upon the former model, and, therefore, did not support hypothesis 3c.

Qualitative investigations

To investigate our fourth set of hypotheses, we explored children's statements about their strategy use (see Figures 1-3). Figure 1 displays explained strategy use per constructed analogy of 'subgroups' of children based on condition and their number of correctly constructed analogies at the transfer session.

Figure 1. Solution strategies (non-analogical and implicit analogical) explained per child and condition, divided by the number of correctly constructed analogies: 0 correct, 1 correct, and more than 1 correct. Strategies[1]: 1=copy; 2=part copy; 3=procedural; 4=story; 5=don't know; 6=own rule; 7=implicit analogical. *The (partial) absence of a bar represents verbalizations including at least one correct transformation.*



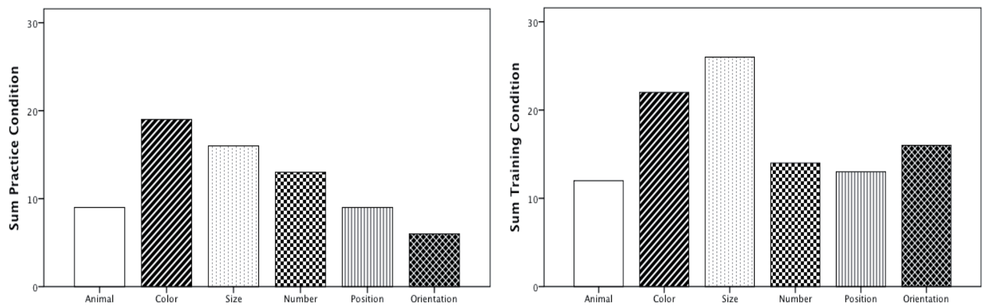
Note: [1]a more elaborate description can be found in Appendix B. The group of children with zero correctly constructed analogies displayed the greatest variation between conditions in their strategy use. Children in the training condition displayed more explicit analogical strategy use, and more of their 'own rules' than the practice condition. Moreover, the training condition displayed hardly any 'copy' strategies, while the practice condition displayed a considerable amount of 'copy' strategies. The children with one correctly constructed analogy tended to use – in both conditions – the same non-analogical strategies ('own rule' and 'don't know'), besides implicit and explicit analogical strategies. The group of children with more than one correctly constructed analogy mainly used explicit analogical strategies, beside some 'don't know' and implicit analogical strategies.

Overall, children in the training condition constructed 'more than one correct analogy' more often than just 'one correct analogy', while the practice condition showed the opposite. Hypothesis 4a was confirmed (see Figure 1).

Hypothesis 4b was partially confirmed. As expected, children in the practice condition who were unable to construct any correct analogy provided more 'copy' explanations. However, contrary to our expectations, they often also included their own rules and hardly ever told stories about the animals or gave procedural information, as they had done after solving the traditional analogical tasks (Pronk et al., submitted).

We also hypothesized (4c) that transformations would be explained most frequently by reference to color, size and number. We expected the more challenging transformations, 'orientation' and 'position', to be identified less frequently. Figure 2 demonstrates that, indeed, this pattern was found for the practice condition.

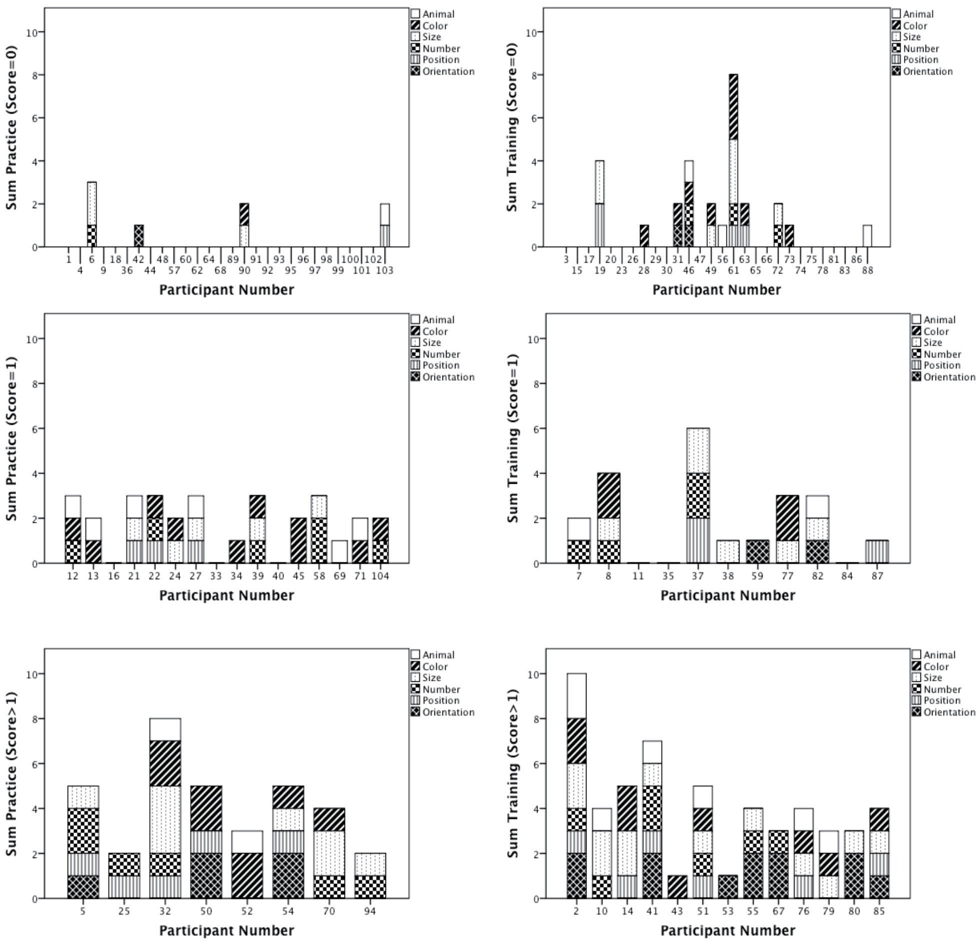
Figure 2. Type and number of transformations explained at the transfer session by condition



The results for the training condition were somewhat different, however (see Figure 2). Here, children explained more transformations and made more frequent references to the 'more difficult' transformations (orientation and position).

Figure 3 offers a more in-depth look at the distributions displayed in Figure 2. Here, it can be seen the subgroups of children presented in Figure 1, which were based on condition and their number of correctly constructed analogies at the transfer session.

Figure 3. Type and number of transformations explained per child by condition and number of correctly constructed analogies: 0 correct, 1 correct, more than 1 correct.



The largest differences are those between the lowest and highest performing subgroups. In the former, where children were unable to construct a complete analogy, several children from the training condition, but none from the practice condition, were able to display or explain analogical strategy use. In the latter, where most children were from the training condition, a larger variety of explained transformations per child were evident.

5.4 Discussion

In this study we sought to assess the depth and breadth of changes in analogical performance, induced by either a dynamic test-type-training or repeated practice experiences. Although initial performance and progress on traditional analogical tasks predicted how well children would fare on the self-construction analogy task, it was the children's partial performance (such as use of only a single transformation), rather than complete solutions, that was the key predictor. This had been expected as other studies have shown that high-level mastery in analogical performance is needed to detect transfer of learning at this level (e.g. Siegler, 2006; Day & Goldstone, 2012).

The analogy construction tasks in the current study, especially the more complex ones, were difficult to fully master in such a relatively short study period (Tzuriel & George, 2009), particularly for children of this age (Halford & McCredden, 1998). It was notable that partial construction scores were important even after initial capacity and working-memory had been held constant. Clearly, we can conclude that the capacity to solve analogies is related to the capacity to construct them (see also, Harpaz-Itay, Kaniel, Ben-Amram, 2006; Bosma & Resing, 2006). The relationship we found between spatial working-memory and analogy construction confirmed earlier studies as well (e.g., Rasmussen & Bisanz, 2005; Tunteler et al., 2008; Halford et al., 2010). Unsurprisingly, children were better constructors when they executed their analogical strategies (more) efficiently (Siegler, 2006). These outcomes indicate that those who progressed further with the construction tasks, acquired a more thorough or 'deeper' understanding of the underlying principles involved. After all, while constructing analogy tasks, children needed to extract the earlier learned analogical relationships from schemas in their memory, rather than working out existing relationships in the tasks presented to them (Perkins, 1992; Harpaz-Itay et al., 2006; Martinez, 1999).

It is interesting that the dynamic-test-type training appeared to provide no additional improvement in task performance over that of repeated practice alone. Perhaps, for a quantitative effect to emerge, the training will need to be rendered more extensive by adding more items or an extra session in between the final practice sessions (e.g., Tzuriel & George, 2009).

Children in the training condition explained a greater percentage per possible transformation and were more likely to refer to the more difficult types of transformations: orientation and position (Siegler & Svetina, 2002; Stevenson et al., 2011). While this was a specific feature of high achievers, it was noticeable that this also applied to poorer performers. Apparently, even many of them had understood and retained several of the taught analogical relationships, and were able to successfully access, apply and cite these (Harpaz-Itay et al., 2006). Furthermore, although the greater number of fully correct analogies produced by children in the training condition *at the transfer stage* was not statistically significant, they often provided qualitatively different explanations for these solutions. Where their constructed analogy was incorrect, they obviously had created their own rules. They rarely demonstrated the more simple solution strategies that complete novices often show, such as mere copy strategies, as was the case for many of the children in the practice condition (Sternberg & Rifkin, 1979; Siegler & Svetina, 2002). The evidence from the qualitative part of our investigation suggests that training was having an effect on the breath of change, but the training procedure may need to be more substantial for quantitative differences to become possible to emerge.

Although many children in the practice condition cited copying strategies for solving their self-constructed analogies, they also often included their own rules and, in contrast with the earlier assessment sessions, rarely reverted to storytelling or procedural strategies. It is possible that multiple choice, and even constructed response analogical task formats, encourage children to adopt strategies such as copying and storytelling (Martinez, 1999; Stanger-Hall, 2012; Morrison, Doumas, & Richland, 2011). However, a more empty task, such as the one used in this study, may encourage the deployment of more creative solutions.

Future studies should investigate whether creative solutions of this nature, garnered from either dynamic testing or practice situations, are able to provide additional data about the child's developing problem solving capacities.

In the somewhat different domain of science, creative reasoning, where children generated self-made analogies during their lessons, has been found to be an important precursor in their understanding of natural phenomena, (e.g., Pittman, 1999; May, Hammer, & Roy, 2006; Haglund, Jeppsson, & Anderson, 2012). These self-generated analogies revealed children's previously acquired knowledge and experience, and appeared to encouraged them to process the material deeply and consequently gain understanding of underpinning structural relations (e.g., Blanchette & Dunbar, 2000; Harpaz-Itay et al., 2006). Assessment of children's constructed analogies, using non-academic, domain general tasks, such as those used in the present study, could possibly reveal their current depth of general understanding of the complexity of analogical strategies. Examining children's differential responses to training and practice on analogy construction tasks has the potential to offer educational psychologists and teachers additional insights into the stability of the individual's reasoning processes.

The current study has shown that an analogical construction task, serving as a measure of transfer, can provide additional information about young children's depth of learning and learning potential. Such information, perhaps in combination with working-memory assessment data (Alloway, Gathercole, & Pickering, 2006; Alloway & Gathercole, 2006; St. Claire-Thompson & Gathercole, 2006), may prove to be of practical benefit to teachers (May et al., 2006), although more research is needed to justify such a claim. More specifically, this study suggests that knowledge of the types of strategies children utilize and verbalize can yield insights and understanding about (individual) children's readiness for learning. Such a conclusion has important implications for both individual and larger scale educational dynamic-test situations and particular curricula areas (e.g., Grigorenko, 2009; Haglund et al., 2012), for example in science education or math. Whether analogical construction tasks provide more valuable information to educationalists when these are domain specific (e.g. relating to math or science content) or domain general, such as the task reported in the present study, is a question that requires further investigation.

Appendix A

Hint procedure for the transfer tasks

Nr	Hint	Procedure
1	[*If* a child does not get started proceed with the first hint.] What was it that you needed to do? First you choose (animal) cards for the first two cells, for example for these two (point to A & B cells) or for these two (point to A & C cells), and you lay down these cards. Do you remember now?	If the child gets started, no more hints are provided until cards have been laid down in three of the four cells of the matrix. Otherwise proceed to the next hint.
2	After that, you think about which cards you want to put into the last two cells, so that everything goes together. Do you remember now?	Same as above.
3	Then you put down the cards for the third cell and you leave the last cell open. After that you may tell me what I need to do.	If a child is still unable to construct something that looks like an open-ended figural analogy, move on to the next task.

Note: Children were given up to three hints (if needed), so that 'their puzzle' looked like the open-ended figural analogies that they had solved during the practice and dynamic training sessions. Hints were only provided to help a child get started if he/she didn't start on their own. Hints were not provided to explain how a proper analogy should be constructed.

Appendix B

Scoring system of the figural analogies

Category[1]	Description	Example
1. Copy	The child indicates that their solution is a copy of another cell of the analogy.	'It's this one', while pointing to another cell of the analogy.
2. Part copy	The child indicates that s/he has copied part(s) of other cell(s), and the behavioral solution confirms this.	'I took that one and that one, but not that one', while pointing to specific animals relating to another cell.
3. Procedural	The child gives simple information about picking up particular animal cards and putting them in the empty cell.	'I picked up this card and put it down here. I also wanted to lay down this one, but it didn't fit.'
4. Story	The child tells a story about the animals.	'This horse likes that one and this is the mummy and that is her baby.'
5. Don't know	The child indicates ignorance as to how he or she solved the puzzle.	'I don't know', 'I guessed', 'I just liked it.'
6. Own rule	The child indicates that s/he made up a rule and applied it to the analogy. However, this isn't a correct transformation.	'I made this one blue, because there was no blue yet.' Or: 'One bear plus one, so this one needs two.'
7. Implicit analogical	Correct transformations are clearly present in the behavioral solution, but the child only refers to them implicitly.	'I made it just like there,' while pointing to the top two cells and then to the bottom two cells.

Note: [1]Categories were created in accordance with children's answers and partially derived from the work of others (e.g., Siegler & Svetina, 2002; Tunteler et al., 2008).