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Changes over time and transfer of analogy-problem solving of gifted and non-gifted children in a dynamic testing setting

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ABSTRACT

This study examined differences in transfer of analogical reasoning after analogy-problem solving between 40 gifted and 95 average-ability children (aged 9–10 years old), utilising dynamic testing principles. This approach was used in order to examine potential differences between gifted and average-ability children in relation to progression after training, and with regard to the question whether training children in analogy problem-solving elicits transfer of analogical reasoning skills to an analogy construction-task. Children were allocated to one of two experimental conditions: either children received unguided practice in analogy problem-solving, or they were provided with this in addition to training incorporating graduated prompting techniques. The results showed that gifted and average-ability children who were trained made more progress in analogy problem-solving than their peers who received unguided practice experiences only. Gifted and average-ability children were found to show similar progression in analogy problem-solving, and gifted children did not appear to have an advantage in the analogy-construction transfer task. The dynamic training seemed to bring about no additional improvement on the transfer task over that of unguided practice experiences only.

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Dynamic testing; gifted; transfer; analogy problem-solving

Introduction

Applying knowledge to a new context is an important necessity in order for gained knowledge and skills to be of use in everyday life outside the classroom context (Day & Goldstone, 2012), and is therefore one of the main aims of education. Groups of children have been found to differ in the extent to which they transfer learned knowledge and skills. Some groups of learners have been found to have an advantage in transfer of learning, one such group being the gifted. Gifted children have long been thought to have an excellent ability to transfer learning to a new situation (e.g. Renzulli et al., 1997).

Various studies have shown that eliciting transfer of learning to new contexts proves difficult (Bransford, Brown, & Cocking, 2001; Day & Goldstone, 2012; Gick & Holyoak, 1983), possibly due to its complex (Nokes-Malach & Mestre, 2013), and idiosyncratic nature

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(Kyllonen, Lohman, & Snow, 1984). Transfer has been noted for its potential to reveal important insights into children's potential for learning (Bosma & Resing, 2006; Ferrara, Brown, & Campione, 1986). Therefore, in dynamic testing, transfer of newly acquired knowledge and skills is one of the measures used to gain insight into a child's potential for learning (Sternberg & Grigorenko, 2002; Tzuriel, 2007). In contrast with conventional static testing, dynamic testing is a form of testing that incorporates feedback and instruction, sometimes tailored to the individual, into the testing process (Elliott, 2003; Jeltova et al., 2007), and is focused on the potential for learning, rather than on previously acquired skills and knowledge (Resing & Elliott, 2011).

In the present study, we applied dynamic testing principles to examine whether cognitively gifted and average-ability 9 and 10 year old children would show differential changes in analogy problem-solving, and patterns in their ability to transfer analogy problem-solving skills to an analogy-construction task. All the children in the present study received opportunities for unguided practice in analogy problem-solving. Half of the children, however, received an additional training in analogy problem-solving, which enabled us to investigate whether training would lead to more changes over time in problem-solving than unguided practice, and facilitate transfer of the learned skills.

Dynamic testing outcomes are assumed to provide a more detailed picture of a child's cognitive potential (Elliott, Grigorenko, & Resing, 2010), and strengths and weaknesses (Jeltova et al., 2007), than conventional, static testing procedures, such as intelligence or school aptitude tests (Elliott, 2003). This form of testing has been found to be especially beneficial for special populations, such as ethnic minority, or learning disabled children (Robinson-Zañartu & Carlson, 2013; Sternberg & Grigorenko, 2002). Perhaps due to these reasons, the large majority of research into dynamic testing has focused on special groups of children. Studies into dynamic testing of gifted children, however, are few. Findings of such studies have revealed that gifted children not only outperformed their non-gifted peers, but also showed significantly more improvement (Calero, García-Martín, & Robles, 2011). Moreover, young gifted children were found to have a wider zone of proximal development, to learn new skills faster, and to be better at generalising new knowledge (Kanevsky, 1990, 2000).

Dynamic tests often employ inductive reasoning tasks (e.g. Ferrara et al., 1986; Resing & Elliott, 2011). Inductive reasoning is assumed to be related to a large variety of higher-order cognitive skills and processes, including general intelligence (Klauer & Phye, 2008), problem-solving (Richland & Burchinal, 2012), and applying knowledge and skills (Goswami, 2012). Analogical reasoning, a subtype of inductive reasoning, is considered to play a central role in cognitive development (Klauer & Phye, 2008; Pellegrino & Glaser, 1982), and develops significantly throughout childhood (e.g. Leech, Mareschal, & Cooper, 2008). Children with strong cognitive capacities, such as gifted and talented children, are often found to achieve higher scores on analogical reasoning tasks (e.g. Caropreso & White, 1994).

Several studies in the field of dynamic testing have revealed that training incorporating graduated prompting techniques can lead to improvement in reasoning by analogy (Bosma & Resing, 2006; Ferrara et al., 1986; Stevenson, Heiser, & Resing, 2013). Graduated prompting techniques, as used in the present study, refer to a form of an intervention in which children are provided with prompts each time they make a mistake in problem solving. In the current study, prompts are tailored to each individual problem to be solved, and become more specific gradually, from metacognitive to cognitive prompts and modelling (Resing & Elliott,

2011). These techniques are used increasingly in combination with a pretest-training-posttest format, as in the present study, a specific form of dynamic testing that allows for structured measuring of children's progression in learning (e.g. Ferrara et al., 1986; Resing, Bakker, Pronk, & Elliott, 2016; Resing & Elliott, 2011).

Analogical reasoning involves defining and deciding that two problem-solving situations are similar, and, ultimately, successfully transferring previously problem-solving experiences to new situations that can be, partially, dissimilar. Unsurprisingly, reasoning by analogy is considered to be closely related to the ability to transfer (Gentner, Holyoak, & Kokinov, 2001); both require that one observes an analogy or similarity between two problems (Chi & VanLehn, 2012; Holyoak, 1984). In general, two factors have been proposed to play a role in transfer: the content, the exact problem that is being transferred (Barnett & Ceci, 2002), and the context (Klahr & Chen, 2011), which refers to the different domains from and to which the problem is being transferred. Researchers often distinguish in different types of transfer on the basis of the surface similarity of the base and target problem, including near versus far transfer (Mestre, 2005), and surface versus deep transfer (Forbus, Gentner, & Law, 1995). If the base and target share few surface similarities, and are thus less similar, the more cognitively demanding the process of transfer becomes (Gentner, Loewenstein, & Hung, 2007). Transferring effectively involves mastery of the task to be transferred (Siegler, 2006), and a deep rather than surface understanding of the task at hand is required for deep transfer (Barnett & Ceci, 2002).

It is often assumed that gifted children transfer knowledge more efficiently than their non-gifted peers (e.g. Klavir & Gorodetsky, 2001; Zook & Maier, 1994). Research into the transfer ability of this group of children has revealed that, on near transfer tasks, gifted children's performance seems similar to their non-gifted peers (Carr, Alexander, & Schwanenflugel, 1996). In far transfer tasks, however, gifted children were found to outperform their non-gifted peers (Geake, 2008; Kanevsky, 2000). Kanevsky (1990) reported that, after learning new strategies, gifted learners spontaneously transferred these strategies to new learning contexts. The underlying processes facilitating transfer in the gifted population are not yet fully understood, but Carr and colleagues (1996) suggest that gifted learners are more likely to transfer their acquired strategies to other domains, as they show an elaborate understanding, and make more use of complex strategies.

As eliciting transfer is challenging (e.g. Barnett & Ceci, 2002), a variety of studies have been carried out investigating whether training facilitating deep understanding or mastery of a task could promote transfer. Several studies have revealed that training children in solving inductive reasoning problems led to higher levels of generalising skills learned during training to similar and dissimilar problems (e.g. Harpaz-Itay, Kaniel, & Ben-Amram, 2006; Roth-van der Werf, Resing, & Slenders, 2002; Tzuriel, 2007). In the present study, we utilised a 'reversal' procedure to measure transfer. Having had practice opportunities, or practice opportunities in combination with a short training in analogy problem-solving, participants were asked to construct their own analogy items, similar to the ones they had solved before, which then had to be solved by the examiner (Bosma & Resing, 2006; Kohnstamm, 2014; Stevenson et al., 2013). As such, this task required a reversal of roles.

In order to promote transfer of problem-solving strategies practiced or trained, we kept the surface features of our analogy construction task similar to those of the open-ended visuo-spatial geometrical analogy items children solved before (Resing et al., 2016), assuming that children would use previously acquired knowledge and skills in their constructed

analogies (Day & Goldstone, 2012). Previous research, however, has shown that despite these similarities in surface structure, the analogy construction task is a challenging and difficult task for children (Bosma & Resing, 2006; Tzuriel & George, 2009).

The present study had two main aims. Although consideration of the occurrence of transfer was our primary research aim, we were also interested in whether children's analogy problem-solving would improve differentially. Firstly, we sought to examine children's potential for learning. We expected that training by dynamic testing would lead to more change in children's analogy problem-solving than unguided practice only. We anticipated larger progression in accuracy scores of the children who were dynamically trained than the children who received unguided practice only (Stevenson et al., 2013; Tunteler, Pronk, & Resing, 2008). We further anticipated that progression in accuracy would be larger for gifted than average-ability children, and there would be a significant interaction between session, condition and ability group for the accuracy scores (Calero et al., 2011).

We also considered the time it took children to complete all of the items of a test session. We expected that results for children in the unguided practice would show a decrease in completion time, but not for those in the dynamic testing condition, as we expected that training would lead children to spend time on strategic considerations (Resing, Tunteler, & Elliott, 2015). We also expected a significant three-way interaction of Session \times Condition \times Ability group as to children's completion time, and hypothesised that gifted children would be more time efficient than their average-ability peers, considering they are assumed to be better in self-regulation (Calero, García-Martín, Jiménez, Kazén, & Araque, 2007).

Our second research question concerned the transfer of learned skills. As proposed by Clerc, Miller, and Cosnefroy (2014), in-depth assessment of transfer requires the measuring of both performance, as well as the degree of transfer achieved. Therefore, in the current study, we focused on both the transfer accuracy scores, as well as on the difficulty level of the analogies constructed by the children. We expected that, in comparison with children in the unguided practice condition, trained children would show higher levels of transfer accuracy scores; as well as difficulty levels of accurately constructed analogies (Roth-van der Werf et al., 2002). In addition, we expected that gifted children would show a higher degree of transfer than their average-ability peers (Geake, 2008; Kanevsky, 1990). We further explored whether children's transfer performance and degree of transfer could be predicted by their analogy problem-solving accuracy scores (Alexander & Murphy, 1999).

Method

Participants

In the present study, 135 children participated, 62 boys and 73 girls, ranging in age from 9 years and 3 months to 10 years and 11 months ($M = 10.10$; $SD = .60$). All the participants were born in the Netherlands, and attended either a mainstream primary school, or a special setting for gifted and talented children in the western part in the Netherlands. All schools participated on a voluntary basis. Gifted children were over-sampled and identified on the basis of a qualitative judgment of parents and teachers regarding their giftedness. Additionally, all of the children in our gifted sample each scored at, or above the 90th percentile on the Raven's Standard Progressive Matrices Test (Raven, 1981). Written permission

of parents and school was obtained for each child prior to participation in the current study. Nine children dropped out in the course of the study, as they did not participate in each test session.

Design

The study used a two-session (pre-test, post-test) repeated measures randomised blocking design with two treatment conditions: dynamic testing versus unguided practice (see Table 1). All children were provided with opportunities to practice analogy problem-solving at pre-test and post-test, with both test sessions taking approximately 20 min to administer. In addition, only the children in the dynamic testing condition received two short training sessions, of approximately 20 min each, between pre-test and post-test. The children in the unguided practice condition did not receive training, but were provided with a two-session control task, in which they were asked to solve figural maths problems. The time taken for this task was similar to that for the dynamic training to keep the time-on-task for all children as equal as possible. Before the pre-test, the Raven Standard Progressive Matrices Test (Raven, 1981) was administered to allocate children to the two treatment conditions. Children who had obtained a Raven percentile score of at least 90 were included in the 'gifted' condition. All other children were included in the 'average-ability' condition. Raven scores were further used to ensure that any differences in initial reasoning ability were as small as possible across the children in the dynamic testing and unguided practice conditions. Within the two ability groups, pairs of children with equal scores (blocking) were randomly assigned to the dynamic testing or unguided practice condition, resulting in four subgroups of children: gifted dynamic testing ($n = 22$), gifted unguided practice ($n = 18$), average-ability dynamic testing ($n = 47$) and average-ability unguided practice ($n = 48$).

Materials

Raven standard progressive matrices test

The Raven Standard Progressive Matrices Test (Raven, 1981), a non-verbal intelligence test measuring fluid intelligence, was used as a blocking instrument. The Raven test results were shown to have a high level of internal consistency in several studies as shown by split-half-coefficients of $r = .91$ (Raven, 1981). In the current study, the 1992 corrected norm scores for the Dutch population were used to calculate percentile scores for the participating children.

Table 1. Overview of the design.

Condition	Groups	Dynamic/static test					
		Raven	Pre-test	Training 1	Training 2	Post-test	Transfer
Dynamic testing	Gifted ($n = 22$)	X	X	Dynamic training 1	Dynamic training 2	X	X
	Average-ability ($n = 47$)	X	X	Dynamic training 1	Dynamic training 2	X	X
Unguided practice	Gifted ($n = 18$)	X	X	Control task	Control task	X	X
	Average-ability ($n = 48$)	X	X	Control task	Control task	X	X

Dynamic test of analogical reasoning

Pre-test and post-test. The dynamic test utilised visuo-spatial geometric analogies of the type A:B::C:?? of varying difficulty, part of a test battery developed by Hosenfeld, Van den Boom, and Resing (1997), and adapted for further use by Tunteler and colleagues (2008). Six basic geometrical shapes were used in the construction of the analogies: squares, triangles, hexagons, pentagons, circles, and ellipses (see Figure 1 for an example of a difficult analogy item, the instructions provided to the children during the pre-test, as well as the correct answer). The original analogy test items were constructed by a maximum of five possible transformations: changing position, adding or subtracting an element, changing size, halving, and doubling. As the original item-sets have been used for young children of various ages, but not for children from the age of nine, the items used in the current study were adapted by adding extra transformations, including rotation and colour. The test was administered as an open-ended paper-and-pencil test, and children drew their answers.

Both the pre-test and the post-test consisted of 21 items of varying difficulty. For pre- and post-test, parallel versions were constructed by keeping the difficulty levels of the items the same, as well as the order in which the items of varying difficulty were presented. Participants received minimal instructions during the pre- and post-test, specifying they had to solve puzzles by filling the empty square with the appropriate shapes. They did not receive feedback on their answers. In our sample of participants, the pre-test was found to have high internal consistency ($\alpha = .85$) for the accuracy scores.

Dynamic training. Two short training sessions each consisting of six new analogy items were administered between the pre-test and post-test to participants in the dynamic testing condition. The training sessions employed graduated prompting techniques used in earlier studies (e.g. Resing & Elliott, 2011). These involve the provision of a number of prompts when the child makes an error in problem-solving. All prompts were administered hierarchically: starting with four very general metacognitive prompts, followed by four specific cognitive prompts, tailor-made for each item. As each new prompt became progressively more specific, this procedure enabled measurement of the child's need for differing degrees of help in order to solve the problem presented. Both training sessions consisted of eight prompts in total, which were only administered after indication that a child could not solve the problem independently.

After each prompt, children were asked to draw the solution of the analogy, and check whether their solution was correct. If a child had not solved the analogy after the seventh prompt had been administered, the examiner modelled the correct answer. After the children's final answer, they were asked to explain why they thought their answer was correct.

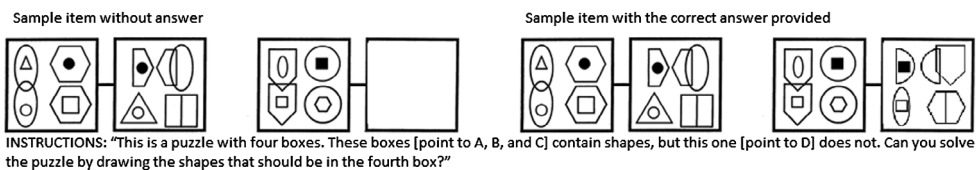


Figure 1. Example of a difficult analogy item, the correct answer and the instructions provided.

Finally, the tester provided a correct self-explanation. Figure 2 shows a flowchart of the training procedure. Figure 3 includes a sample item showing answers children provided at each step of the graduated prompts procedure.

Transfer: analogy construction task

Transfer was measured by means of an analogy construction task. As part of this task, children were asked to construct their own analogy, so the examiner could solve it. In a sense, the roles were reversed, and the child became the teacher (Bosma & Resing, 2006). Participants were provided with four squares, similar to those used in the previous test sessions, but then empty, and instructed that they could utilise any of the geometric shapes they had seen in prior sessions, and to provide instructions to the examiner on how to solve the analogy. Children were asked to complete two reversal trials, and thus construct two analogies. For both tasks, the children were given short, general instructions only to enhance spontaneous problem-solving behaviour. After construction of the analogy item, the child had to ask the examiner to solve the item, and, on completion of the analogy by the examiner, then had to explain why this was the correct answer.

General procedure

Children were tested once weekly, in accordance with the schools’ availability, over a period of six consecutive weeks. All parts of the present study were administered individually, following standard, protocolled instruction. At the beginning of the pre-test, training and post-test sessions, the children were provided with the six geometrical shapes used in the analogies, and, in cooperation with the examiner, named each shape, after which the examiner asked the child to draw the shapes below the printed shapes, staying as close to the original as possible (Tunteler et al., 2008). It was assumed that this procedure helped activate children’s prior knowledge, ensured that the examiner and child used the same terminology when addressing the geometric shapes, and facilitated the scoring procedure. The test sessions were administered by master’s students of psychology, who, prior to testing, received

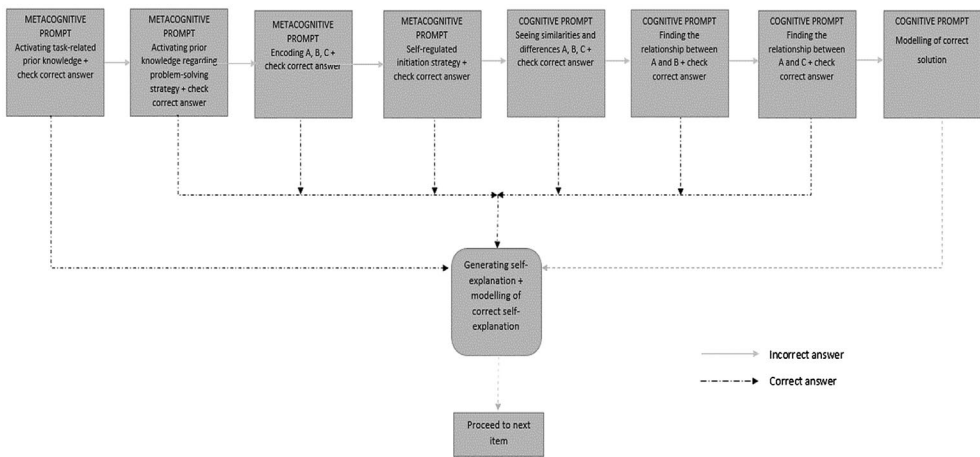


Figure 2. Flowchart of the graduated prompts training protocol.

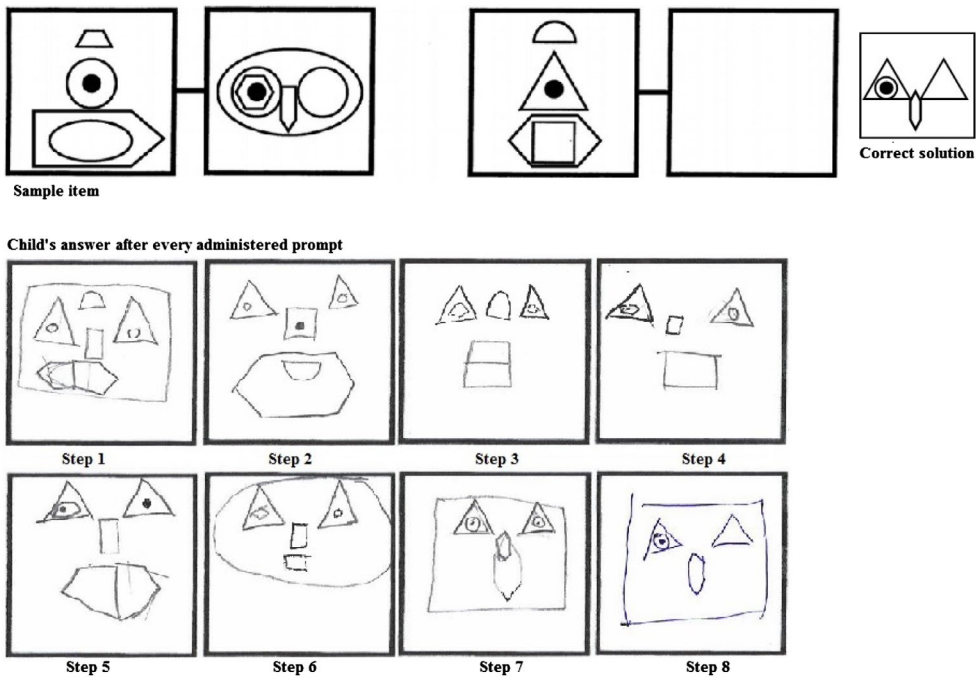


Figure 3. Sample item of an analogy item used in training 1, including a child's solutions provided after every prompt.

extensive training in working with the test protocols. For each child, all the test sessions were administered by the same examiner.

Scoring and analyses

The outcome variables of the pre-test and post-test sessions consisted of the accuracy score, the total number of correct items per session, and the completion time, the time (in seconds) it took each child to solve all the items of the pre-test and post-test.

We examined two outcome variables of the analogy construction task: transfer accuracy, and difficulty level. Outcome variables were (1) the sum of accurately constructed analogies (range 0–2), and (2) the transfer difficulty. In former research, it has been suggested that the number of different elements an item contains, as well as the number of transformations necessary to solve the analogy correctly are indicative of the difficulty level of an analogy item (Hosenfeld et al., 1997; Mulholland, Pellegrino, & Glaser, 1980; Tunteler et al., 2008).

In concordance with former studies, in the present study the difficulty level of a constructed analogy was calculated by means of the equation correctness of the analogy constructed $(1/0) \times$ the number of transformations used in the construction of the analogy (1–8) (Mulholland et al., 1980; Stevenson et al., 2013). As the children were asked to construct two analogy items, their accuracy score ranged from '0', no correct analogy item, to '1', one correct analogy item, to '2', two correct analogy items. A constructed analogy was considered correct if, in addition to being solvable, the item contained at least two of the shapes used in the items part of the preceding test sessions, and at least one transformation from A to B that

could also be applied from C to D. All children’s responses were scored by the examiner, and checked by the first author. Prior to data analysis, the examiners were provided with extensive training in data collection, and scoring.

The total difficulty level score obtained by each child (range 0–14) was calculated by adding the difficulty level scores of both items. Both outcome variables were considered to be ordinal, violating the assumptions of least-squares regression. Therefore, we conducted ordinal logistic regression analysis (Agresti, 2010). The regression analyses included the following predicting variables: condition, ability group, condition × ability group, post-test accuracy score, and condition × post-test accuracy score.

Results

Initial group comparisons

Prior to analysing our research questions, we evaluated possible differences between the two experimental conditions, and ability groups, respectively. The children in the two conditions did not differ in their age ($p = .48, \eta_p^2 < .001$) or initial reasoning performance (Raven accuracy score; $p = .97, \eta_p^2 < .001$). Children in the gifted and non-gifted groups also did not differ in age ($p = .85, \eta_p^2 < .001$), but did in their initial reasoning performance ($p < .001, \eta_p^2 = .48$). We further evaluated possible differences in pre-test performance, and found no significant differences in accuracy scores, or in completion time between children in the two experimental conditions. Gifted and non-gifted children were found to differ on their accuracy scores ($p < .001, \eta_p^2 = .16$), but not on their completion time ($p = .29, \eta_p^2 = .01$). Basic statistics for the measures used in the current study are provided in Table 2.

Analogy problem-solving

Our first research question concerned changes in analogy problem-solving. Changes over time were examined by means of two repeated measures ANOVAs with one within-subjects factor Session (Pre-test – Post-test), and two between-subjects factors Condition (dynamic

Table 2. Basic statistics of the analogical measurements, divided by condition and ability group.

			Dynamic testing			Unguided practice		
			Gifted	Aver- age-ability	Total	Gifted	Aver- age-ability	Total
Raven	Accuracy scores	<i>N</i>	22	47	69	18	48	66
		<i>M</i>	49.73	38.94	42.38	49.89	38.69	41.74
		<i>SD</i>	2.51	5.90	7.15	2.78	6.18	7.41
Pre-test	Accuracy scores	<i>M</i>	10.77	5.91	7.46	9.83	7.08	7.83
		<i>SD</i>	4.38	4.14	4.77	4.29	3.71	4.04
		Completion time	<i>M</i>	1267.45	1207.52	1266.63	1331.09	1199.09
		<i>SD</i>	302.80	564.37	494.54	367.80	471.58	446.87
Post-test	Accuracy scores	<i>M</i>	15.41	11.83	12.97	11.06	8.27	9.03
		<i>SD</i>	3.42	4.89	4.76	5.13	4.15	4.57
		Solving-time	<i>M</i>	1055.05	1104.34	1088.62	1075.78	1027.42
		<i>SD</i>	226.26	329.50	299.65	270.99	325.55	310.34
Transfer	Accuracy scores	<i>M</i>	1.77	1.66	1.62	1.94	1.50	1.70
		<i>SD</i>	.43	.60	.65	.24	.72	.55
	Complexity	<i>M</i>	8.00	7.40	7.59	6.89	5.46	5.85
		<i>SD</i>	3.10	3.31	3.23	2.70	3.36	3.24

testing versus unguided practice) and Ability group (gifted versus average-ability). Children's accuracy scores and completion time at Pre-test and Post-test were used as the dependent variables. In Table 3, the main and interaction effects of the repeated measures ANOVAs are provided. Results for accuracy scores revealed significant main effects of Session ($p < .01$, $\eta_p^2 = .39$), and, most important for answering our hypothesis, a significant Session \times Condition ($p < .01$, $\eta_p^2 = .20$) interaction, but no significant Session \times Ability group ($p = .39$), or Session \times Condition \times Ability group interaction ($p = .36$). Inspection of Table 3 led to the conclusion that, only partially in accordance with our hypotheses, dynamically trained children, irrespective of their ability group, showed significantly greater progression in solving analogies than control-group children. The slopes of the progression lines of the two dynamically tested groups of children did not significantly differ, indicating that children in both ability groups made comparable progress in accuracy although they started at different levels. The between-subjects effects of Ability group for accuracy supported this finding, $F(1,131) = 23.42$, $p < .001$, $\eta_p^2 = .15$.

A second aspect of children's analogy solving concerned the time they needed to complete all tasks of a test session. Although we expected that completion time would decrease for the children in the unguided practice condition, but not for the trained children, the repeated measures ANOVA showed only a significant main effect of session ($p < .001$, $\eta_p^2 = .14$), but no significant interaction effects (see Table 3). Contrary to our expectations, all groups of children showed a comparable decrease in their completion-time from pre-test to post-test.

These results led us to conclude that training leads to more improvement in accuracy than practice opportunities, as assumed, but, unexpectedly, that training and unguided practice both led to a decrease in solving time. Gifted and average-ability children seemed to differ in terms of the number of items solved correctly, as expected, with an advantage for those who were gifted, but, in contrast to our hypotheses, not in terms of change from pre-test to post-test, and training benefits in relation to both accuracy scores and completion time. Of course, individual differences in scores and changes in scores were large for children in both ability groups and conditions.

Transfer of analogy problem-solving

Our second research question concerned children's performance on the analogy construction transfer task. Ten children were unable to construct any accurate analogies, with eight

Table 3. Results of the repeated measures ANOVAs for the accuracy scores, and completion time.

	Wilks' λ	F	η_p^2
Accuracy scores			
Session	.62	82.09***	.39
Session \times Condition	.80	32.39***	.20
Session \times Ability group	.99	.76	.01
Session \times Condition \times Ability group	.99	.84	.01
Completion time			
Session	.86	21.75***	.14
Session \times Condition	1.00	.49	<.01
Session \times Ability group	.99	1.47	.01
Session \times Condition \times Ability group	1.00	.03	<.01

*** $p < .001$.

children constructing items that were partial analogies, and two constructing items that were non-analogical. Out of 135 children, 27 and 98 children, accurately constructed either one, or two analogies, respectively (see Table 4). As a further exploration of the data, the children who had been able to construct accurate analogies were divided in three groups, based on the difficulty level of the analogies they constructed: low, medium, and high. Considering that it was the first time we used construction of geometric analogy items as a transfer task, as an explorative analysis, we investigated possible individual differences in transfer and the effect of training by equally dividing the children *post hoc* into three groups, based on the number of transformations their self-constructed analogies contained. Chi square tests revealed that children in the unguided practice condition constructed more analogies of a low difficulty level than the trained children ($\chi^2(1, N = 37) = 4.57, p = .03$), that trained children designed more difficult items than non-trained children ($\chi^2(1, N = 41) = 5.49, p = .02$), while the children who had constructed analogies of medium difficulty level were distributed evenly ($\chi^2(1, N = 47) = .53, p = .47$). These findings revealed a first indication of the effect of training on transfer accuracy and difficulty level.

In addition, two Mann-Whitney U tests were conducted, one for each condition, to explore whether gifted and average-ability children were distributed evenly in relation to the difficulty level of the analogies they constructed. The results revealed that gifted and average-ability children were distributed evenly across the three difficulty level groups in the dynamic testing ($U = 448, z = -.53, p = .60$), and the unguided practice condition ($U = 392, z = .24, p = .81$).

An ordinal regression analysis was conducted to examine whether the number of accurately constructed analogies could be predicted by condition (dynamic testing versus unguided practice), ability group (gifted versus average-ability), and post-test accuracy. The results (see Table 5) revealed that the post-test accuracy score ($p < .001$) could significantly predict transfer performance. Although neither condition ($p = .18$), nor ability group ($p = .50$) significantly contributed to prediction, the condition \times ability group interaction did ($p = .04$). The interaction showed, contrary to our hypotheses, a negative effect, indicating lower scores for gifted children who were trained.

Table 4. Children’s transfer accuracy and difficulty level, divided by condition and ability group.

	Dynamic testing			Unguided practice		
	Gifted	Average-ability	Total	Gifted	Average-ability	Total
Inaccurate analogies						
Non-analogical	0	0	0	0	2	2
Partial analogical	0	3	3	0	5	5
Accurate analogies						
Low difficulty (2–6 transformations)	4	7	11	8	18	26
Medium difficulty (7–9 transformations)	10	16	26	5	16	21
High difficulty (10–16 transformations)	8	20	28	5	8	13

Table 5. Results of the regression analyses for transfer accuracy and difficulty level (correct \times transformations).

	<i>b</i>	SE	Exp (β)	χ^2
Accurate analogies ^a				
Condition	2.16	1.59	8.64	1.83
Ability group	.48	.71	1.61	.45
Condition \times Ability group	-2.75*	1.33	.06*	4.29
Post-test accuracy score	.22***	.06	1.25***	11.82
Condition \times Post-test accuracy score	.09	.10	1.09	.73
Transfer difficulty ^a				
Condition	.14	1.07	1.15	.02
Ability group	.30	.48	1.35	.39
Condition \times Ability group	-.69	.70	.50	.98
Post-test accuracy score	.16	.05	1.18***	10.91
Condition \times Post-test accuracy score	-.01	.07	1.00	.01

* $p < .05$; *** $p < .001$; ^aOrdinal logistic regression.

A second ordinal regression analysis was conducted to examine whether transfer difficulty level could be predicted by condition, ability group and post-test accuracy. The findings indicated that only the post-test accuracy scores contributed significantly to prediction ($p < .001$). In sum, children's post-test accuracy score seemed to be a good predictor of transfer accuracy and difficulty level, regardless of training or ability group. Unexpectedly, however, the gifted children who received unguided practice seemed to outperform the gifted children who were trained in terms of transfer accuracy. An exploration of the quality of the constructed analogies suggested that differences between children were found mainly in the items of lower and higher difficulty group, with training seemingly facilitating construction of more difficult items.

Discussion

The focus of the present study was twofold. We examined gifted and average-ability children's progression in analogy problem-solving after dynamic training or unguided practice. We also focused on whether a dynamic training would facilitate children's performance and degree of transfer, and whether gifted and average-ability children show differences in their transfer accuracy and difficulty level.

We first looked into children's potential for learning. The children who, in addition to unguided practice experiences, also received dynamic training showed steeper progression in accuracy than the children who were not trained, indicating that testing children's ability dynamically shows a more complete picture of their cognitive potential than testing statically (e.g. Robinson-Zañartu & Carlson, 2013). We also focused on potential differences between gifted and average-ability children in relation to changes in analogy problem-solving performance. Our findings suggest, as expected (e.g. Calero et al., 2011), that gifted children outperformed their average-ability peers in accuracy in analogy problem-solving. They did not, however, show differential progression in accuracy or reduction in completion time, which is in contrast to earlier findings (e.g. Kanevsky, 1990, 2000).

This finding could be explained, in part, by the fact that gifted children have been noted for their tendency towards perfectionism (Fletcher & Speirs Neumeister, 2012). Perhaps the gifted children in the current study took longer to solve the analogy items than was strictly necessary, due to perfectionistic tendencies, which could have been activated by working

on a novel task. Whether this played a role in task solving could be further investigated, for instance by studying completion time patterns (Resing, Xenidou-Dervou, Steijn, & Elliott, 2012).

In addition, children who were trained showed similar instead of differential levels of reduction in time needed to solve the analogies to their peers who did not receive training. In earlier research (Resing et al., 2015), it was posited that this might be due to children devoting more time to strategic considerations as a consequence of training. In the current study, however, children had to draw their own answers, which required substantial time and usage of motor skills. Completion time seemed to be dependent on other factors, such as children's fine motor skills, as a result of which the reduction in completion time could, therefore, be ascribed to more familiarity with the task and an improvement in fine motor skills needed for the task.

Our second main aim was to explore potential differences in gifted and average-ability children's transfer of practiced or learned skills. We utilised an analogy construction task (Bosma & Resing, 2006; Harpaz-Itay et al., 2006) in order to examine children's transfer accuracy and difficulty level. First of all, we found that the majority of children could construct an accurate analogy, in contrast with earlier studies in which more children were found to have difficulty with this task (Resing et al., 2016; Stevenson et al., 2013). The children participating in the current study were slightly older than in these previous studies, so we suggest that this is partly due to developments in their analogical reasoning (Leech et al., 2008). Training, however, could not predict transfer accuracy or transfer difficulty level.

Further, children were divided in groups on the basis of the degree to which they could transfer, looking more closely at the difficulty level of the constructed analogy items. We found that the group of children that had constructed analogy items with a high difficulty level contained significantly more children who were dynamically trained, while the group that had constructed low difficulty analogy items consisted of significantly fewer dynamically trained children than children who had received unguided practice opportunities. These findings suggest that, for at least some children, training was necessary in order to construct the more difficult analogy items. Other children, however, did not need training to construct difficult items, reflecting individual differences between children in relation to their analogy problem-solving and construction skills.

Contrary to our expectations, gifted children were not found to outperform their average-ability peers in transfer accuracy as well as difficulty level. It must be noted that in the current study, children had not been formally identified as gifted by means of full scale IQ testing, but were identified on the basis of their parents' and teachers' judgements as well as their scores on the Raven test. Although the Raven test is considered a reliable measure of general intelligence, perhaps utilising a stricter cut-off score than the 90th percentile used in the current study, or taking into account other factors rather than just cognitive factors (Kornilov, Tan, Elliott, Sternberg, & Grigorenko, 2012; Renzulli et al., 1997), would have led to more distinct differences in performance.

Moreover, it must be taken into consideration that the instructions of the transfer task did not specify that children had to construct complex analogies. Instead, they were kept to a minimum to elicit spontaneous problem-solving (Resing et al., 2016). Therefore, it cannot be disregarded that some of the gifted children were not motivated to construct difficult items. Clerc et al. (2014) provided a possible explanation for this finding. These authors stated that self-regulation is strongly associated with the ability to transfer, and that both children

with low self-regulation as well as those with high self-regulation, such as gifted children, as for example demonstrated by Calero et al. (2007), can experience difficulty with transfer. According to them, good metacognition might hinder some children's transfer ability, as they do not want to use the strategy they have learned, before having fully mastered the cognitive processes necessary for utilising the strategy. A child's metacognitive knowledge relating to the transferral of a strategy or skill might be ahead of the child's actual ability to apply the strategy or skill. The fact that the gifted children who received unguided practice outperformed, in terms of transfer accuracy, their gifted peers who were trained lends some support to this explanation; perhaps training enhanced these children's metacognitive knowledge, while their actual ability to apply what they had learned in training was not yet at the same level, making these children unwilling to apply the strategies they have learned to a difficult item.

Clerc et al.'s (2014) explanation might also, in part, account for the fact that training, contrary to our expectations, could not predict transfer accuracy or difficulty level. Other explanations could be that the tasks were too difficult for some of the children to achieve deep understanding in a short time-frame (e.g. Tzuriel & George, 2009), or that the training employed in the current study was too short. In future studies, it might be useful to make the training more intensive, for example by increasing the number of sessions, or the number of items per training session (Resing et al., 2016; Tzuriel & George, 2009). More research, however, is necessary to investigate exactly what type of training is beneficial.

Moreover, measuring transfer by means of an analogy construction task is a rather novel approach (Resing et al., 2016; Stevenson et al., 2013). Perhaps the shift from analogy problem-solving to analogy construction was too challenging for the children to unveil their true potential in analogy construction, as a result of which the effect of training did not transfer to analogy construction. Therefore, future studies could combine the analogy construction task with repeated practice opportunities, possibly in combination with a short training intervention. In previous research by Campione, Brown, Ferrara, Jones, and Steinberg (1985), for example, children were provided with training as part of a transfer task in analogical reasoning.

In addition to the limitations mentioned above, the current study had some other limitations. The most important limitation concerns the relatively low number of participants in the subgroups. Due to the small sample sizes of our study, it is, of course, not possible to draw far-reaching conclusions. The effect sizes of the analyses, however, were found to range from large for main effects and interaction effects between session and condition, to small for interaction effects including ability group. Therefore, research replicating the current study employing larger sample sizes certainly is a necessity. Finally, it must be noted that the children in the dynamic testing condition had more exposure to analogy problem-solving than the children in the unguided practice condition. In future studies, therefore, it would be advisable to use an extra experimental condition, so that, during the training phase, one group of children receives training, one group receives additional practice, and one group receives an unrelated control task (as used, for example, by Stevenson et al., 2013).

Finally, the present study contributed to the existing research into transfer as we investigated both transfer accuracy, and complexity, and, thus, looked into both transfer performance and the degree of transfer obtained by the children (Clerc et al., 2014). The findings from the present study support Siegler's (2006), and Day and Goldstone's (2012) suggestions that mastery of a skill is a requirement for transfer to occur, especially at the deep level, and

that transfer at the deep level is challenging for young children (Clerc et al., 2014; Resing et al., 2016). Only a small number of children could construct more difficult items, the majority of whom had received training in analogy-solving. Children showed considerable individual differences in their progression in accuracy, as well as their performance and effectiveness of transfer, findings that could only partially have been captured by traditional, static testing. In that sense, it seems plausible that dynamic testing might be a valuable instrument in capturing the underlying processes involved in progression in performance, as well as transfer in relation to learned skills.

Disclosure statement

No potential conflict of interest was reported by the authors.

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