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PhD THESIS

- summary -

ANALOGICAL TRANSFER.
COGNITIVE MECHANISMS AND MODIFIABILITY

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Summary of PhD Thesis

INTRODUCTION AND OBJECTIVES OF THESIS

Analogical reasoning is a form of inductive reasoning and is considered to be the central element of the human cognitive system by many outstanding researchers of the field of cognitive sciences (Hofstadter, 2001; Hofstadter, Sander, 2013, Kolonder, 2002).

The main objective of the thesis entitled „*Analogical Transfer. Cognitive mechanisms and modifiability*" is to synthesize the most important results in the field as well as to elaborate a computer based research and development program. The program simulates natural situations and through the solving of analogical challenges allows the study and modification of cognitive and metacognitive components which determine the performances of analogical transfer. Researches included in the thesis are structured on three levels. The first level contains the researches that aim at the cognitive and metacognitive components of analogical transfer and reasoning. On the second level the psychological aspects of analogical reasoning and transfer modifiability are tackled by using an own intervention program based on the plasticity of cognitive and metacognitive mechanisms identified within the first level.

Theoretical Objectives

The thesis aims at determining those cognitive and metacognitive mechanisms which constitute the structure of analogical reasoning and transfer. The presence and role of these cognitive mechanisms are intensely debated in specialty literature. The thesis intends to formulate some argumentative clarifications which refer to contradictions in dominant theories of analogical transfer. The chapters of the paper present the most significant findings regarding analogical transfer and reasoning from the perspective of the existing paradigms in specialty literature.

Methodological Objectives

The first methodological objective of the thesis is the enrichment of the inventory designed to research analogical transfer and reasoning mechanisms. The elaboration of a computer program will allow the attainment of important results regarding the processing of cognitive and metacognitive mechanisms of analogical reasoning and transfer by using very accurate measurements (time of reaction, time of encoding, solving time combined with the number and complexity of the objects and relations between the problem situations).

The second methodological objective of the thesis is to elaborate a complex program for the modification of analogical transfer and reasoning efficiency. The aim is to differentiate those cognitive and metacognitive anchors which have a significant impact on cognitive modifiability.

Practical Objectives

The practical objective of the thesis is to elaborate a computer program which will allow practitioners to assess the functional level of analogical reasoning and transfer in children. We would also like to formulate some practical suggestions regarding the modifiability of analogical reasoning and transfer based on data formerly obtained.

Key words

analogical reasoning, analogical transfer, cognitive mechanisms, metacognitive mechanisms, modifiability, surface similarity, structural similarity, development of analogical reasoning and transfer, componential analysis, mediated learning, problem solving, solving strategies, Analogon program

CHAPTER I.
Theoretical Substantiation of Studies

Theoretical patterns of analogical transfer

Theory of formal disciplines and identical elements

Researches on transfer of learning analyse the cognitive mechanisms that make it possible to use existing knowledge, called source domain, in the formation of new knowledge, called target domain.

Thorndike and Woodworth (1901) initiated the first research in order to verify formal disciplines theory, unanimously accepted and applied by theoreticians of the beginning of the century, regarding the generalized influence of studying certain school subjects (such as Mathematics, Grammar, Chemistry, Physics, Latin) which determine the level of knowledge acquirement from other domains that rely on the same mental processes.

The results of Thorndike and Woodworth's (1901) experiments proved the nonexistence of relations presumed by the formal disciplines theory. Instead, they highlighted knowledge transfer in case of common elements in two school subjects (eg: Latin-French). Learning transfer, according to the theory of identical elements, has at least three forms of manifestation: 1. Performance attained in the acquirement of a task may facilitate performance in learning a new task, if the two have identical characteristics. In this case, the phenomenon known as positive transfer appears; 2. The second type of influence of the source domain on the target domain occurs when the learning of a task obstructs or negatively influences the acquirement of a new task. These situations are characterized by negative transfer, where there are no identical elements in the two domains. 3. The third type is lack of transfer, situations in which the effects of positive transfer are annihilated by negative transfer (Ellis, 1965).

C. O. Osgood's transfer surface theory

The theory of identical elements was adopted by Ch. E. Osgood (1949) and integrated into the transfer surface theory according to which knowledge transfer from the learning context to the performance contexts is determined by the similarity of the stimuli of the two contexts.

M.K. Singley and J.R. Anderson's identical production rules theory

According to ACT theory (Adaptive Control of Thought) (Singley, Anderson, 1989) the amount of transfer between the source and target problem is determined by the number of common production rules required in the problem solving process. The common production rules represent the identical elements in Singley and Anderson's theory (1985, 1989). The authors emphasize the basic conditions for knowledge transfer between two domains: identical syntactic structure and the existence of an identical set of rules based on which the domains can be analysed.

G. Salomon and D.N. Perkins' theory of complexity levels of cognitive processing

Salomon and Perkins (1989) distinguish two ways of achieving transfer depending on the complexity of the cognitive processing involved.

The first way (low road transfer) is characterized by spontaneous production, with no explicit contribution of complex cognitive mechanisms (identification of a similar source, extraction of similar characteristics to those of target domain, decision, etc.)

The second way of knowledge and solving strategies transfer (high road transfer) requires explicit participation of complex cognitive processing and is based on highlighting the relations of similarity between source and target domain through abstraction.

S.M. Barnett and S.J. Ceci's theory of near and far transfer

Starting from the analysis of experiments and deficiencies regarding the concept of transfer, Barnett and Ceci (2002) have elaborated a taxonomy built on two factors: the content and context of situations which imply the reuse of knowledge acquired during the solving of new problems. The authors have included the physical, temporal, functional and socially determining elements of knowledge transfer in the group of contextual factors. Content factors refer to types of information that are transferred from a familiar context to new contexts. These can be formerly acquired skills, knowledge updated from memory, problem solving strategies, expertise, etc. Starting from these content and context factors, Barnett and Ceci (2002) differentiate between two basic types of knowledge transfer: near transfer and far transfer.

Case Based Reasoning theory by J.L. Kolonder

Case Based Reasoning theory by J.L. Kolonder (1992) is a form of analogical reasoning where a new problem is solved by retrieving a similar “case” from memory whose relevant solving strategies are reused through adaptation.

According to the author the paradigm of case based reasoning is mostly founded on observation in concordance with which knowledge formed in real life contexts is characterized by a high level of functioning, determined by the integrated coding of information that provides higher accessibility and adaptability in comparison with the knowledge acquired through learning in school context.

Development of analogical reasoning

Theory of analogical reasoning development stages

According to Piaget’s theory, up to the age of five or six children are not able to solve analogies, as the specific cognitive functions necessary for this type of reasoning are not yet present in their operational system.

The first signs of analogical reasoning appear at the age of seven or eight when the child can already classify the objects and phenomena and by this cognitive processing can solve simple problems of analogy. In conformity with Piaget’s theory, at the age of eleven or twelve children recognize the way objects relate, have the ability of abstracting relations and higher relational thinking appears.

Theories of early development of reasoning and analogical transfer

Experimental results referring to the development and efficiency levels of Piaget’s analogical reasoning and transfer have been reviewed during the years and completed with alternative models for the development of cognitive mechanisms of analogical reasoning and transfer at different ages.

Stage related nature of analogical transfer

Studies that approach problem solving through analogy generally accept the idea of the stage related nature of this phenomenon. The most important stages were highlighted by Holyoak (1984). This concept became quite popular in specialty literature through the years.

Holyoak and Thagard (1995), Gentner et al. (1993), Novick (1988) Keane (1994) isolated the following stages of analogical transfer:

1) Mental representation of source and target;

2) Identification of sources analogous to target problem;

3) Mapping of source and target components;

4) Extension of mapping in order to find the solution to the target-problem.

The central concept of modern analogical transfer theories: similarity

Analogy is based on similarity between two situations. These situations do not necessarily contain the same elements, but there has to be a structural similarity between the elements of the source and target domain. In a number of studies (Gick, Holyoak, 1980, 1983) participants were asked to solve the classic problem of Duncker’s (1945).

CHAPTER II.

Meta analysis: Efficiency of inter and intra domain analogical transfer

Objectives

By meta-analysis of researches that study the effects of intervention programs and methods on inter and intra domain transfer performance, we wanted to obtain data regarding their efficiency. Studies were grouped into two categories: 1. Studies that aim at intra domain transfer and 2. Studies that aim at inter domain transfer.

Characteristics of included studies

1. To compare the efficiency of training for analogical transfer through intra domain pre and posttest
2. To compare the efficiency of training for analogical transfer through inter domain pre and posttest (far transfer)
3. To give details of training procedure
4. To present a control group
5. To provide sufficient data to calculate the value of effect (M, Sd)
6. To provide data regarding the age of participants

Studies which did not meet all the above mentioned criteria simultaneously were excluded from present analysis.

Method

For the identification of studies, a search was carried out in the data bases: EBSCO, Sage, Proquest, using the following key words: analogical transfer, analogical transfer training, inductive reasoning, transfer. Studies were detected by using bibliographic references as well. 40 studies that match the search by key word were found. After applying the criteria for inclusion, 7 studies were retained in the case of which analysis presents sufficient data according to the established criteria. The information presented allows us to calculate the value of effect for 10 experimental situations in the case of analogic transfer in similar context, as well as 6 values of effect for analogical transfer in contexts different from the learning context.

Encoding procedure

Each study was reviewed and only those were adopted that contain information related to age of participants, random assignment into experimental and control groups, type and duration of training. With our objectives in mind, we calculated separately the value of effects for intra and inter domain analogical transfer (far transfer).

Results

We selected studies that circumscribe the chosen topic, as well as elaborated the inclusion criteria presented in the former sections. The two categories were separated based on the information obtained – transfer in similar context and transfer in context different from the learning context. The mean values of effect were calculated for each category and correction formulas were applied for the sample error. The results obtained show an increased efficiency of transfer and thus implicitly of the training for analogical transfer in similar context (D = 1.02). On the other hand, results emphasize a lower, however significant efficiency of transfer to a farther context (D=0.43). According to criteria established by Cohen, in the case of transfer in similar context we have a significant value of effect, and in the second case an inferior mean value of effect. In other words, transfer efficiency decreases as the distance between the context of application of knowledge and that of learning increases.

CHAPTER III.
Cognitive mechanisms of analogical transfer
(Study II)

Theoretical substantiation

For the theoretical substantiation of this study three componential theories of analogical reasoning and transfer are relevant: Gentner's Structure Mapping Theory (1983, 1989), Holyoak's Multiconstraint Theory (1985) and Sternberg's Componential Theory (1977).

Structure Mapping Theory

Gentner's Structure Mapping Theory (1983, 1989) is a theory of analogical transfer according to which the domains to which the terms of an analogy belong are represented within a hierarchical semantic network that contains the data of the problem in the form of objects, object attributes, relationships between objects and abstract relations (higher order relations) derived from relationships between objects (first order relations) (Bender et al. 1986, Anolli et al, 2001, Bianchi and Costello, 2008; Jessup, 2009).Solving a problem by analogical transfer is conditional upon the development of common relational structures between the source and the target domain (Leech et al., 2007) which, according to the author, is carried out by structure mapping and structural alignment of abstract relations that exist between the elements of the domains that define the problem (Chen, 2007).Gentner underlines the fact that the cognitive mechanism of mapping is achieved by the systematicity and transparency of representation of abstract relations (Gentner and Toupin, 1986; Gentner, 2010) between domains: when solving a new problem, participants will develop and use abstract structural relations that refer to the logical determinations between elements of the source and target domain. (Gick and Patterson, 1992; Gross and Green, 2007).

Pragmatic constraints of analogical transfer

The pragmatic reasoning scheme and multiconstraint theory elaborated by Holyoak and Thagard (1989, 1996, 1997) maintains structure mapping of common abstract relations in the componential structure of analogical transfer and emphasizes the role of structural similarity (Holyoak and Koh, 1987) in determining the degree of overlap (comparability) of source and target domain. Starting from critique of Gentner's structure mapping theory that is deemed as lacking ecological validity as it does not take into account the predominantly pragmatic nature of the problem-solving process of "real" problems through reasoning and analogical transfer determined by the content of related domains, namely the influence of the various constraints which modulate information processing in mapping common abstract relationships, the authors demonstrate the role of a new component that plays an important part in determining analogical transfer: induction of solving schemes derived from two or more similar sources accompanied by explicit hints concerning their similar nature. The role of inducing schemes (Robertson, 2000; Ross and Kilbane, 1997) manifests itself in redefining the goals and constraints during the elaboration of the solution, these gaining common functions that determine the achievement of an operational threshold of similarity between domains.

Component mechanisms of analogical reasoning

In the analysis of cognitive processing involved in solving a classical analogy with the form (Bejar, Chaffin, Embretson, 1991): A is for B what is C for D (A: B:: C:D), Sternberg identifies five distinct components of information processing: encoding, inference of relations, mapping, applying the solution and response.

Encoding represents the cognitive component composed of processings that make it possible to transpose the terms of the analogy into mental representations on which subsequent cognitive processings will be performed (Bearman et al., 2007; Butterfield and Nelson, 1991).

Inference represents the process of elaborating a rule that refers to the relation of similarity between the source terms of the analogy (relationship between A:B).

Mapping is the component that determines the correlation rules of source term A with the target term C (Eliasmith and Thagard, 2001; Chen, Honomichl, 2004, Chen, 2007).

Application is a preliminary form with an evaluative nature of the correct response. It consists of the processes involved in elaboration, intermediary implementation and remodelling of a strategy for determining the correct final solution (D) (Gholson et al, 1989; Hammond, 1991; Krawczyk et al., 2004).

Response represents the monitoring and transposal processes of the solutions elaborated in the actual solution (Klauer, 1997; Krawczyk et al., 2005; Leboe et al., 2000; Tseng et al., 2012).

Objectives and hypotheses

The main objective of the study is the modelling of cognitive processes that take place in solving non verbal analogy tests, as well as the mapping of cognitive mechanisms that constitute the structure of analogical transfer. Within this objective, we pursued the determination and modelling of successive phases of cognitive processing which occur during the solving process of tasks of nonverbal analogy as well as the measurement of time during which such processings take place.

An important goal of the study is to collect experimental data that provide information on the nature of the analogical transfer: to determine the procedural nature of this basic component of the human cognitive system (Hofstdter, 2001, 2013) that manifests itself in most human activities (learning, problem solving, creativity) and the characteristics that define the analogical transfer as a cognitive skill of a general nature which acts independently from the content and context of the cognitive task.

Hypotheses

1. There is a multiple influence on performance and solving time of the tasks of non verbal analogic reasoning exercised by the logical complexity of tasks and the presence or lack of information having the role of feedback concerning the correctness of the responses.
2. The second specific hypothesis regarding the determination of the predominant procedural or aptitudinal nature of analogic transfer implies the delineation of components or cognitive mechanisms that constitute the structure of this process, or the delimitation of characteristics independent from the context and nature of information processing that would constitute arguments for the defining of analogical transfer as independent cognitive skill.
3. If the results of the study reveal the existence of general solving strategies that apply to all the tasks included in the experiment, a unitary cognitive model of the structure of analogical reasoning and transfer can be elaborated. If participants apply noticeably different solving strategies for different types of tasks, then there are various models that differ through the structure of cognitive mechanisms engaged in solving the tasks of analogical reasoning.

Method and Procedure

Participants

100 primary school students of Hungarian nationality from Cluj participated in the experiment. The students were aged between 7.0-10.8. Of the 100 participants, 59 are boys and 41 girls. The average age is 9.0 and age dispersion is 0.9.

Tools

In this study, we used the following programs and tests: a computer program named Analogon, J. A. Naglieri's Matrix Analogy Test as well as the subtests "digit span" and "encoding" from the WISC IV test.

J. A. Naglieri's Matrix Analogy Test

The test is used to assess nonverbal intelligence and inferential reasoning in students aged between 5 and 17. The test items are grouped around four structural factors of nonverbal intelligence: Pattern completion, Analogical Reasoning, Serial Reasoning and Spatial Visualization.

We used the Digit Span subtest from Wechsler's intelligence scale for children – fourth edition- which measures the functional level of working memory. The subtest known as "Encoding" of this scale was also applied, relevant for information processing speed, which is a very important parameter in the study of cognitive mechanisms of analogical transfer.

The ANALOGON Program

The Analogon computer program has been developed based on the results of basic researches on analogical reasoning (Sternberg, 1997, 2009; Holyoak, 1985; Gentner, 1989) and on theories of componential analysis of analogical transfer structure processes. It permits the study of cognitive mechanism functioning in primary school students while solving analogical reasoning tasks of progressive complexity. The program models the solving procedure specific for analogical transfer.

The program is independent of platform and can be installed on any computer running a version of Windows or a compatible operating system (XP or higher if possible). To run the program a graphics card and an integrated sound card is sufficient. The design has taken into account the fact that the program should also operate on laptops. The program consists of two modules: 1. an interface for design and editing, and 2. an interface for the presentation and recording of responses and response times.

The basic structural components of the Analogon program are: the matrix, the field and the window. Tasks that need to be solved by the participant always appear on a matrix. Each matrix consists of four windows. All four windows of the matrix are divided into four fields. Windows are marked with Roman numerals, and the fields from inside the windows with Arabic numerals. The tasks are presented on the windows numbered with Roman numerals (I-III), and window no. IV is the answer window.

During the course of solving Analogon tasks, regardless of the purpose of use (experimental, testing or intervention with the goal of cognitive development), participants can only use window IV for response. These are the fixed, and unparameterizable characteristics of Analogon (Figure 1.).

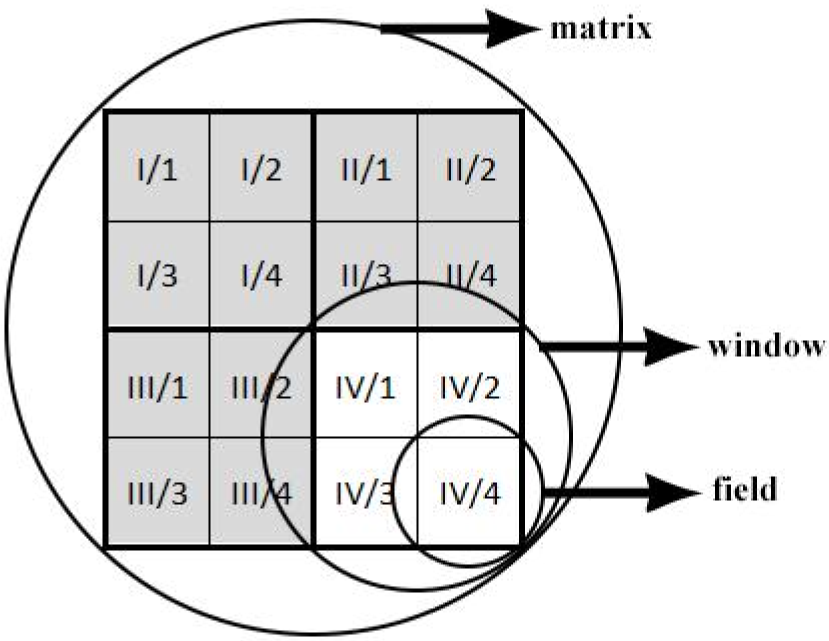

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Figura 1. Components and indexing of Analogon items

In the case of Analogon program, participants were presented with 24 tasks (items) of nonverbal analogical reasoning structured on four levels of difficulty and two degrees of complexity. Each level and degree of complexity contains two tasks (items) of learning and a test item. Test items (8 for the whole program) are logically isomorphic with one of the learning tasks presented, and use the same set of shapes as in the case of learning tasks.

The Analogon program records the experiment and research sessions in full. This means that the database contains all the information on the basis of which the solving steps, the types of errors, their number, the time used for each task, the duration of solving each item, as well as the total duration of the experiment or the session can be analysed.

In the case of each of the 24 items the information gathered from the solving process of each participant was registered in eight variables:

1. position factor: how many times the subject has selected location during task solution
2. information concerning selection of wrong position: how many wrong location selections took place
3. information about colour: how many times the colors have been selected, the number of possible selections is 74
4. wrong choice of colour: how many times the wrong colors have been marked.
5. choice of shape: number of shape selections
6. wrong choice of shape: the number of erroneous selections of shapes
7. use of negative metacognitive checking component: how many times the subject has selected the icon ☹ meant to delete the item or selection made; this number is equal to zero in the case of perfect response.
8. use of positive metacognitive monitoring component: how many times the subject has selected the icon ☺ which is intended to complete the task.

On the basis of data related to time five variables have been created for each task:

1. time of first response (TFR): the time from the moment the task was assigned until the participant made the first decision, regardless of its correctness, materialized by the first selection of an item that can be considered to be a response
2. time for selection of position (TP): how much time the participant has dedicated to selecting locations during task solution
3. time for colour selection (TC): time dedicated to colour selection
4. time for shape selection (TS): time dedicated to shape selection
5. time for the elaboration of the correct response (TCR): the time devoted to making the correct decisions

The sum of time variables 1-5 constitutes the total time of task solution (TTS). This amount includes the value of the variable time of first response, too (the first selection of location, colour or shape).

Results

In the first phase the analysis of Analogon items was carried out. The comparative analysis of the parameter "solving time" aimed at highlighting the presence and extent of the influence of cognitive analogical transfer mechanisms on solving tasks of nonverbal analogy represented by the items of the Analogon program. From the way the extent of solving times evolves, depending on level of complexity (I to IV namely the complexity of learning items), the type of items (learning, test), the degree of similarity, several conclusions related to the structure and efficiency of analogical transfer mechanisms can be drawn:

1. The extent of solving time reflects both the number of cognitive mechanisms present in the elaboration of response and the efficiency of these mechanisms. Thus, the solving time obtained in the case of learning items reflects the number and complexity of cognitive mechanisms present in information processing. The increased solving time in the case of lower-level and low complexity items indicates low efficiency or lack of transfer element.
2. Progressive decrease of solving times between learning items, respectively between learning and test items is a significant indicator of the presence of analogical transfer mechanisms. Participants who achieve lower values of time in case of test tasks than learning tasks, respectively solving times in progressive decrease between learning items, efficiently develop solving schemes which they can transfer to new contexts.
3. Solving time of items involving simultaneous processing of several categories of information from upper levels (III-IV), reflects the ability of the participants to elaborate and induce solving schemes in contexts of some relatively new problems by using simultaneous encoding of elements of perceptual nature (surface similarity) with verbal encoding (structural similarity) of the characteristics of the components. These results are consistent with the results obtained by Chen and Schooler (1999).

Table 1.
Mean and standard deviation of total solving times depending on the main characteristics of Analogon items in tenths of a second (N = 100)

Level	Degree of complexity	Phases	M	SD
1	1	1	167,06	91,66
1	1	2	102,24	44,71
1	1	3	120,55	52,37
1	2	1	258,90	152,20
1	2	2	148,54	75,94
1	2	3	137,28	59,50
2	1	1	174,92	95,25
2	1	2	167,48	71,42
2	1	3	136,32	63,67
2	2	1	235,32	121,24
2	2	2	373,85	199,44
2	2	3	283,90	163,95
3	1	1	281,34	127,29
3	1	2	262,27	116,59
3	1	3	273,39	111,59
3	2	1	474,60	248,37
3	2	2	647,99	313,44
3	2	3	578,19	354,97
4	1	1	405,42	199,21
4	1	2	516,11	259,69
4	1	3	399,45	345,92
4	2	1	396,08	174,20
4	2	2	540,94	239,69
4	2	3	419,69	195,98

In the evolution of average total solution time depending on the level, degree of complexity of the items and phases, at least two features that demonstrate the presence of analogical transfer mechanisms can be observed:

1. The majority of solving time averages of items belonging to transfer phase are lower than average learning items. Decrease of the value of the total solving time in test-phase items is determined by the transfer of solving strategies elaborated on items of logically isomorphic learning phases.
2. Decrease of value of average total solving time between learning items: the second learning item is usually solved more quickly than the first item of learning.

Table 2.
Main and interaction effects of the variables level, complexity and phase on task solving time (N = 100)

Main effect/interaction	df	F	p	η^2	D
Levels (I-IV)	*3*	257,42	0,0001	0.62	2.55
Degree of complexity (1,2)	*1*	281,82	0,0001	0.15	0.84
Phases (1.learning, 2.learning, 3.test)	*2*	21,20	0,001	0.02	0.28
levels* degrees of complexity	*3*	73,11	0,001	0.12	0.73
degrees of complexity * phases	*6*	19,66	0,001	0.04	0.40
levels* phases	*2*	15,86	0,001	0.01	0.20
levels * degrees of complexity * phases	*6*	6,30	0,001	0.002	0.08

These values indicate that the "psychological" difficulty of items is determined primarily by the number of elements to be processed in order to determine the correct response, regardless of position, shape or colour. The value of F and the value of effect in the case of levels*degrees of complexity interaction are worth noting. Although in the case of main effect values both variables have remarkable influence on the total cumulative solution time ($F (3,97) = 73,11$; $p = 0.0001$, $d = 0.73$), this does not result in the essential changing of difficulty of tasks to be solved that should lead to a significant increase of the solving time.

Evolution of solving time depending on the level*degree of complexity (Figure 3) shows that learning tasks of complexity 2of level III are the most difficult, and not the tasks of level IV.

The value of the triple interaction is also worth mentioning: degrees*complexity levels *phases which in spite of appearing to be significant ($F_{(5.95)}$ = 6,30; p = 0.0001; d = 0.08) the value of effect on the dependent variable is minimal.

The study of correlation of response times achieved in solving the Analogon program items with MAT factors provides a range of information on the structure of cognitive mechanisms of analogical transfer. Table 3. contains only significant correlation coefficients between Analogon items and the main factors of the MAT.

Table 3.
Significant correlation coefficients between Analogon items and MAT factors

Analogon Items	Pattern completion	Analogical Reasoning	Spatial Reasoning	Spatial Visualization
L.1.1.1.			**-0,22***	
L.1.1.2.	**-0,20***			
L.2.2.1.				**-0,21***
L.3.1.1.	**-0,29****	**-0,27***		
L.3.1.2.	**-0,41*****	**-0,49*****	**-0,39****	**-0,25***
L.3.2.1.			**0,21***	
L.4.1.1.	**0,20***			

Correlation coefficients with minus sign are explained by the fact that there are items in the Analogon program whose cognitive mechanisms measured by the MAT rather increase than reduce the time needed for the solution. It also means that in the case of the two tests, besides the common cognitive mechanisms, there are some mechanisms that act only in one of the tests.

The results of the Digit span subtest in the WISC-IV test show a significant negative correlation with the solving time in the case of five items of the Analogon program. (Table 4.)

Table 4.
Correlations of solving time of Analogon items with subtests WISC IV

Analogon Item	Memory of figures	Encoding
L.1.2.1.	**-0,29****	
L.2.1.2.		**-0,35****
L.2.2.2.	**-0,24***	
T.2.2.	**-0,25***	
L.3.1.1.	**-0,30****	**-0,24***
L2.21.2.	**-0,28****	
T.3.1.		**-0,29****
L.4.2.1.		**-0,34****

These results mean that the performance of memory while working influences solving time only in the case of some tasks. The result of the Encoding instrument negatively correlates with solving time in the case of four items. These results lead to a conclusion according to which the solution of Analogon items, in their great majority, does not depend on the speed factor of data processing when this is measured with psychometric instrument.

Participants who while solving the first items allot more time to the orientation in space of the problem and to the understanding of constraints, realize the similarity of structure which determines in the case of the following items their proceeding directly to the solution, without resuming the encoding and mapping procedures. The existence of successive resuming mechanisms while encoding and mapping during the process of orientation and understanding of constraints is sustained by the extent of the correlations (Table 5.) between encoding time and participant results in MAT.

The results obtained in the Completion of Stencils factor depend to a great extent on the participants' ability of comparing. The highest correlation coefficient values are to be found in the Completion of Stencils factor. In the items of level 2 (L.2.2.1 and L.2.2.2.) the significant correlation is determined by the time used for orientation and understanding of changes in the solving strategy: unlike the previous items, the solution does not only consist in the determination of the position of elements but also the way in which these are combined.

Mean encoding time does not correlate with the results of subtests WISC-IV. Consequently, individual differences concerning level of working memory do not affect the length of encoding time.

Table 5.
Correlation coefficients between Encoding time (ET) and results of MAT factors.

Level	Completion of Stencils	Analogical Reasoning	Spatial Reasoning	Spatial Visualisation
L.1.1.1	0,20*		0,21*	**0,33****
L.1.1.2.	**0,22***			0,20*
L.1.2.1.	**0,33****	0,22*	0,20*	0,27**
L.1.2.2.	**0,27****			
L.2.1.1.	**0,22***			
L.2.2.1.	0,36**	0,31**	0,32**	**0,42*****
L.2.2.2.	0,36**	0,31**	0,32**	**0,42*****
T.2.2.	**0,29****	0,22*	0,21*	
L.3.1.1.	**0,40*****			0,33**
L.3.1.2.	**0,40*****	0,26*	0,23*	0,20*
T.3.1.	**0,39****	0,34**		0,22*
L.3.2.1.	**0,30**			
L.3.2.2.	0,24*	**0,35****		0,23*
T.3.2.		0,22*	**0,27****	
L.4.1.1.	0,21*			**0,27***
L.4.1.2.	**0,33**	**0,33****	0,30**	0,24*
T.4.1.	0,21*			
L.4.2.1.	0,29**	**0,30****		0,29**
L.4.2.2.	0,20*		0,21*	**0,29****

Factorial Map

The relative position of the 13 factors (6 factors concerning position decision, 4 factors for decision concerning colour and 3 factors for shape decision) and the dimensions that determine their grouping have been checked through multidimensional scaling method.

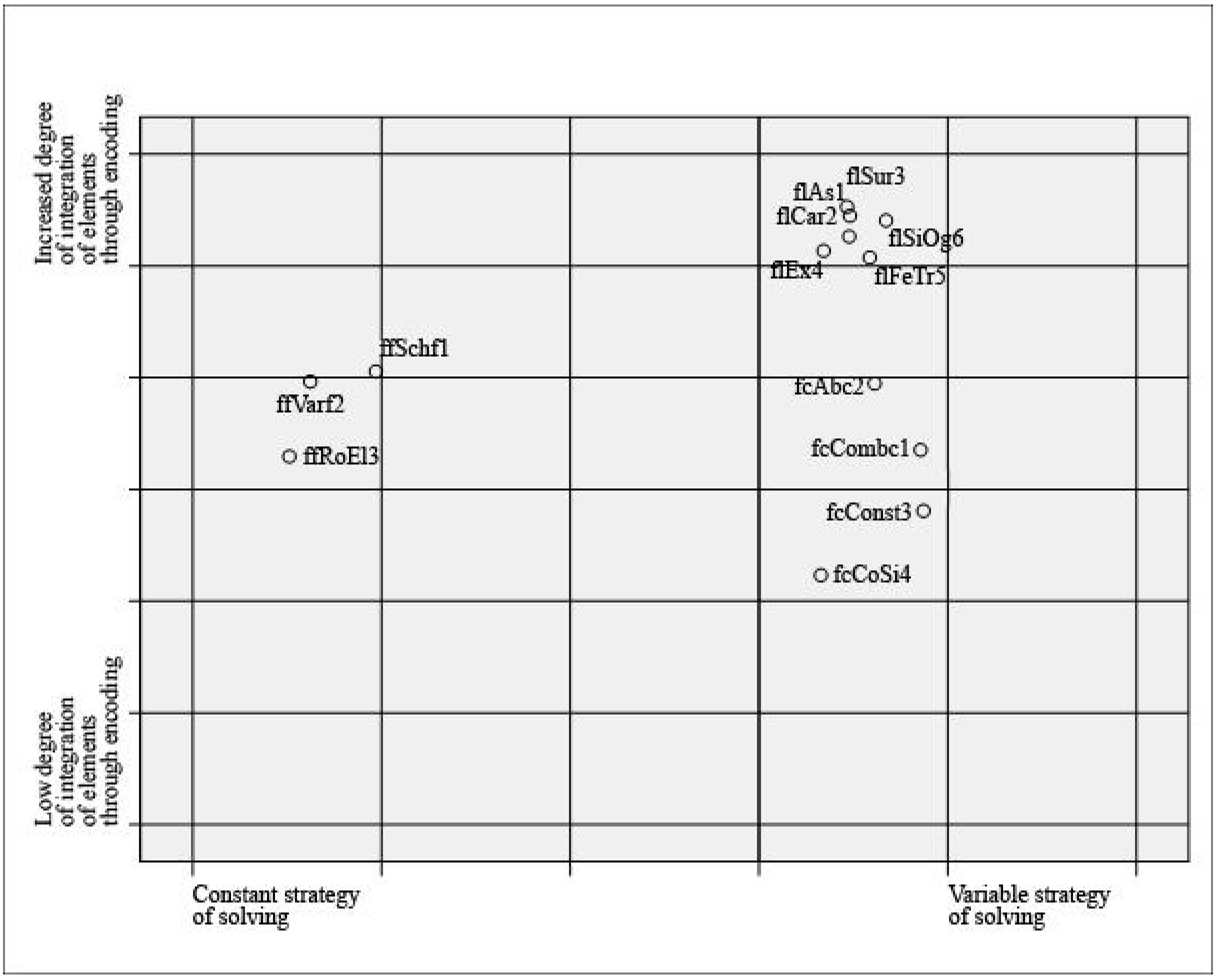

Figure. 2. Relative distances of schemes of associations between Analogon items related to the categories of colour, position, shape flAs1=”Asymmetry”position factor; flCar2=”Cardinality” position factor; flSur3=”Surprise” position factor; flEx4=”Expertise” position factor; flFeTr5= ”Feedback vs. Transfer” position factor; flSiOg6= ”Symmetry in the mirror” position factor; fcCombc1=”Combination of colours” colour factor; fcAbc2=” Colour abstraction” colour factor; fcConst3=”Constant” colour factor; fcCSi4=”Synchronous colouring” colour factor; ffSchf1=”Changing of shape” shape factor; ffVarf2=” Variable function of shape” shape factor; ffRoEl3=” Rotating elements” shape factor;

Discussions and Conclusions

Close correlations are noted between the results of the Analogon experiment and some subtests of the MAT (Completion of Stencils, Spatial Visualisation), which means involving the same mechanisms. Working memory does not correlate with the performances in the Analogon program. Other studies (for example Waltz et al., 2001) reported an association between the phonological component of working memory and performance in analogical transfer. Waltz et al. (2001) used verbal samples, we used non-verbal ones, and thus the highlighted differences have their origins in the very nature of the problems. Neither did these studies succeed in highlighting the role of executive functions of the working memory in analogical transfer. Kyllonen and Christal (1990) showed that analogical reasoning is a much more complex mechanism than working memory, this statement being underlined by our findings as well.

The analysis of results highlights the effect of a cognitive mechanism that manifests itself in the transfer of solution schemes in the case of the items in which the solution of analogy is predominantly based on exclusive encoding of images without the intervention of verbal mechanisms. When solving some of the items (for example those based on cardinality or changing of shapes, so the encoding of information involves verbal formulation) the effect of transfer is decreased. The results of the Analogon items that can be solved by exclusive processing of the image code, correlate with the results of Stencil Completion and Spatial Visualisation scales that measure the ability of processing spatial relations among the elements that are part of the items. Our results, according to previous studies (Cubukcu and Cetintahre, 2010) suggest that the way of encoding influences transfer performance.

Although the results concerning the main variables of the Analogon program do not correlate with the sex and age of participants, still there is a differentiation of these related to the level of schooling. This means that the solving of Analogon tasks also includes metacognitive elements that are developed during school years and are manifested in participants attending higher grades. This particularity manifests itself in relation with the time allotted to the solving of Analogon and MAT items by the participants. Therefore, elaboration time of response is a synthetic indicator that reunites the cumulative influence of functioning level of cognitive mechanisms of the analogical transfer, the elements of strategies while solving the problems studied in class (Mathan and Koedinger, 2005), and also the result of motivational level of participants. The Analogon program can be an instrument of developing all these components of cognitive performance.

An important conclusion of the study refers to the variable intensityof manifestation of analogical transfer depending on the levels and degree of complexity of tasks in the Analogon program. The analysis of results depending on the items, validates the existance of a dichotomy in the manisfetation of cognitive mechanisms of analogical transfer: in the case of the items whose solution is based on symmetry while encoding source-target information and working out the response, in items with a similar structure a massive decrease of encoding time is to be noted, this being determined by the fact that the participants explore the characteristics of the new item, determine the degree of similarity with the previous task and pass on directly to work out the response. For items containing elements which involve reshaping solution scheme (for example when cardinality criterion appears, the set of shapes changes, etc) cognitive mechanisms resume the encoding of source-target information for each criterion (shape, position, colour, cardinality), all this will certainly lead to the increase of time necessary to work out the response. In a study, Williams, Feist and Richard (2007) showed that the design and complexity of encoding items in computer games directed towards the solution of analogies, influence the process of learning.

It can also be noted that analogical transfer in the case of items with symmetric and respectively asymmetric structure has a differentiated manifestation. Statistic indicators of the main variables analysed in the experiment show noticeably different results for the two categories of items: in tasks with symmetric structure the presence of analogical transfer is more emphasized than in asymmetric tasks. This result represents the effect of a cognitive mechanism that appears only in items with symmetric structure: during the information encoding process for delimitation of position (the question "where" the elements have to be placed within the frame) the participants specify and place in advance some elements of the response in the answer field. The participants, who first code colour, permanently associate this element with the processing of the information referring to delimitation of position and shape. Participants, who begin with processing information related to position/shape when working out the response, allot more time to encoding colour information. It should be noted that delimitation of symmetry degree between source and target components allows participants the integrated encoding of multiple criteria that represent a cognitive mechanism of analogical transfer.

An important conclusion related to the functioning of cognitive mechanisms of the analogical transfer while solving non verbal analogy problems refers to the relative equality of solution time in the two main encoding style groups (colour and shape/position). This result emphasizes the similar efficiency of different encoding styles while working out the correct response, as well as the fact that analogical transfer is achieved by employing multiple versions of processing source/target information and with the use of different solving strategies. As such, within the stages of solving the analogies different structures of cognitive mechanism of the analogical transfer may take effect. Although the results in specialty literature concerning the stages that make up the process of analogical reasoning (Sternberg, 1977; Holyoak, 1996) are concurrent, the structural uniqueness of cognitive components that work in these stages cannot be sustained. There are several characteristic types of working out the correct responses and predominant information encoding styles.

The results of the experiment emphasized a number of statistic parameters of the analogical transfer relevant to the use of Analogon program as an instrument of research, diagnostic and as a method of developing analogical reasoning. Thus, from among indicators of time necessary for working out the correct response, the following have diagnostic value: total solving time of the 24 Analogon tasks, the average time used to determine position, the average time used to determine colour, the average time used to determine shape, the ratio between average encoding times and the average of total time for solving the Analogon program. Similarly, in examining the effectiveness of cognitive mechanism functions the following indicators that refer to the total number of mistakes made by the participants during the process of solving the items, have diagnostic value: total number of mistakes, the ratio of the number of mistakes regarding the determination of position and the total number of errors, the ratio of the number of mistakes regarding the determination of colour and the total number of errors, the ratio of the number of mistakes regarding the determination of shape and the total number of errors, the ratio of the number of items solved without mistakes and the total number of items.

CHAPTER IV.
Modifiability of cognitive components involved in analogical transfer
Study III

Theoretical substantiation

Cognitive modifiability represents a fundamental characteristic of the human cognitive system that, in accordance with Piaget's (1965) psychogenetic theory, is the result of phase-specific interiorisation of concrete actions through assimilation and accommodative mechanisms. Vigotsky (1971, 1972) identifies the source of cognitive modifiability in interactions of mediation between the subject and the environment, which causes the progressive evolution of cognitive competences.

According to Feuerstein's (1979, 1991, 2010) theory, cognitive modifiability is characterized by three defining dimensions: permanence, centrality and pervasiveness. Permanence defines the sustainability of changes that appear as a result of the development of cognitive mechanisms through mediated learning. Centrality highlights the formation through mediated learning of those cognitive mechanisms that constitute the basic elements of the human cognitive system, and pervasiveness refers to the property of elaborated processing through mediated learning to modify the functional level of information processing systems.

Objectives and hypotheses

The main objective of the study is to identify and analyse the effects of formative interventions on the level of cognitive components involved in the analogical transfer during problem solving. The formative interventions used were structured according to the main stages of data-processing procedure –input, elaboration and output –that allows differentiated study of cognitive component modifiability involved in the analogical transfer specific for each stage.

The second objective of the study is to analyse cognitive processing on different efficacy levels of cognitive functioning through highlighting specific differences between participating groups depending on the following variables: extent of transfer, represented by the ability of participants to use, through remodeling and adaptation, the solving schemes constructed on basis of formative interventions, and the amount of external prompts, used to elaborate accurate solving strategies.

1st hypothesis: the amount of transfer may be considered the indicator of cognitive profit capacity and of cognitive modifiability. Participants with different amounts of transfer are characterized by different cognitive modifiability.

2nd hypothesis: The functional level and the extent of modifiability of cognitive mechanism in the analogical transfer are directly reflected in the amount of prompts necessary during the elaboration of correct solving strategies (McDaniel et al., 2009). The analysis of prompt amount and types of hints being used according to the stages of information processing and the difficulty of the task allow demonstration of complexity levels of the cognitive components involved.

Method and procedure

Participants

In the experiment 89 children were included from among the group of participants who took part in Study I. The participants were divided into two groups according to the results obtained when solving the Analogon program. The first group (N = 31) includes participants who achieved a high rate of transfer (hereinafter referred to as the Group with high transfer rate), while the second group (N = 58) was composed of participants with low transfer rate (hereinafter referred to as the Group with low transfer rate).

Tools

For the study of cognitive component modifiability in analogical transfer that is highlighted in the ANALOGON program, the *Children`s Analogical Thinking Modifiability Test* (elaborated by D. Tzuriel and P. Klein, 1985) was used. The test was administered together with the *External Prompt Inventory*, elaborated by the author.

Prompt inventory

The main types of prompts have been used for:

1. Focusing attention (metacognitive help) aims at raising awareness and developing the ability of orienting visual exploration and maintaining attention depending on relevant information for the correct solution. In the External Prompt Inventory the number of prompts has been recorded and it shows the number of interventions related to maintaining attention to task. The effectiveness of this type of prompting has been studied by other researchers (Larson et al., 1985; Butterfield, 1991; Burns, 1996; Catrombe, 1994, 2002, Mathan and Koedinger, 2005).
2. Facilitation of the strategy to obtain a solution through setting solution stages is a prompt of metacognitive type whose objective was to offer some general descriptions of the tasks to be solved. The information given through this type of prompts is the plan of "cognitive browsing" while solving a problem by the method of analogy: that is orientation of the problem in space (what is the target to be achieved, which are the main operations that should be carried out, etc.) (Chen et al., 1995; Anolli et al, 2001; Ball et al., 2010; Butler et al., 2012).
3. Prompts targeting analytical perception belong to the input phase of information processing based on the information encoding mechanism. A number of authors consider information encoding processes to be a central cognitive mechanism of analogical transfer. (Loewenstein et al., 1999; Zamani, Richard, 2000; Williams et al., 2007; Tseng et al., 2012). The extent to which these prompts are used indicates the ability to code the main characteristics of the tasks. (For example, small blue circle, etc.) (Fuks et al, 2003, 2004; Colvin, 2008)
4. Selection of relevant information represents a prompt of elaboration type and consists in the delineation of surface and structural similarities that are necessary in elaborating the correct solutions. (Gick and McGarry, 1992; Anolli et al., 2001; Chen, 2002; Kostic et al, 2010).
5. Offering declarative knowledge represents those interventions in which the participants were guided in describing correctly the characteristics of the elements of the source problem (Reeves and Weisberg, 1994; Nahinsky et al., 2004). Such prompting was used mainly in primary encoding of the tasks (for example, big red square, triangle, etc.).

6. Prompting in the form of procedural knowledge relates to particular interventions depending on information processing that is specific for a cognitive mechanism in the structure of analogical transfer (Chen, 2002 a, b; Phye and Sanders, 1992; Phye, 2001) (for example, you have to put something yellow there, Which figure having this colour has its place there? etc.).
7. Prompts on working memory level are the ones that refers to activating information necessary to work out the correct response. (For example, don't forget that you must also set the order in which shapes overlap, etc.) (Kyllonen, Christal, 1990; Klauer, 1997)
8. Information processing through the integration of multiple constraints has been used in cases when the participant, after several attempts, failed to use simultaneously multiple constraints in determining the correct response. (For example, you have to find out the shape and colour of figures and the order of overlapping, etc.). (Holyoak, Nisbett, 1988; Holyoak et al., 1994).
9. Prompting to model exploratory behaviour through the comparison of elements has been given by using the concrete object models (Pugh, Babes, 2006). Participants who did not succeed in working out the correct response by using the interventions described above, have built a concrete model of the correct response by using shapes of different sizes and colours cut out from wood.
10. Interventions meant to control behaviour were of metacognitive type and refer to the way in which the participant communicates the correct response (for example, just think how you solved the problem, do not forget anything, etc.) Tzuriel, George, (1991, 2009; Bereby-Meyer et al., 2005; Ball et al., 2010; Butler et al., 2012)
11. Prompting given in the elaboration of new analogies has targeted the activation of procedures, or correction of sequence of stages while solving the problem through elaboration of analogies (such as the model of Holyoak et al., 1994 and the constraints imposed by Kershaw et al., 2013).

Results

Table 6.
Generating new analogies depending on the amount of transfer and the level of complexity of tasks

Complexity level of tasks	High transfer rate N=31	Low transfer rate N=58	χ^2	p=
Easy tasks	100%	35%	35.44	0.000
Medium complexity tasks	94%	24%	38.98	0.000
Complex tasks	81%	19%	31.91	0.000

The results show a significant determination relationship concerning the ability to elaborate new analogies by applying solution patterns assimilated by the contrast groups. The significantly different effect of the influence caused by the task's degree of difficulty can also be noted both within experimental groups and between groups.

Analysis of the results depending on the type of help used by the two experimental groups during solving analogies show that the most commonly used type of prompting by both groups was the one of metacognitive nature that facilitated the focus of attention. Although the significance of the difference between the average usage of this type of prompting by the groups of contrast is not high ($t = 1.38$; $p = 0.17$), starting from the same extent of frequency of its use in the experimental groups, it appears that metacognitive elements are present regardless of the level of functioning of cognitive mechanisms and determines especially orientation in the space of the problem by maintaining attention in light of information relevant to solving the problem. The deepest contrast between the experimental groups appears in case of prompting aimed at working memory. It is a type of help used mostly by the participants belonging to the group with a low transfer rate ($t=7,43$; $p=0,0001$). This evolution of the results is determined by the fact that in case of the participants with low transfer rate while solving complex tasks the relevant elements necessary for the solution are not activated. Participants belonging to the group with high rate of transfer are much more effective in the formation of a mental pattern used in the process of drafting and solving of the analogies in which they can integrate and maintain relevant information actively. A global analysis of prompting type averages shows a scale that measures with high validity (Cronbach

$\alpha = 0.98$) certain characteristics of cognitive processing involved in solving the problems through reasoning and analogical transfer.

Discussions and conclusions

Study results confirm the differentiating diagnostic value of prompting types and the quantity used to highlight their level of complexity and the extent of their modifiability (Halpern, 1998). Obviously, experimental groups of contrast have used significantly different amounts of external hint types centred on developing and optimizing different cognitive mechanisms from the structure of analogical transfer. The fact that metacognitive prompting is present in both experimental groups, means that these "anchors" of solving behaviour, although not belonging to the immediate cognitive mechanisms involved in analogical transfer, they still determine the effectiveness of elaborating correct solutions at any functioning level of the cognitive system.

CHAPTER V.

Study IV. a. Metacognitive mechanisms of analogical reasoning and transfer

Theoretical substantiation

A number of studies (Ceci, 1991; Winship, Korenman, 1997; Hansen, Heckman, Mullen, 2003) demonstrate the fact that children's performance in psychometric tests increase linearly with the level of schooling. This linear correlation cannot answer the question whether age or the effect of schooling result in the increase of performance in intelligence tests, as children's age as well grows linearly with the level of schooling. In order to delimit the effects of schooling from age effects Cahan and Cohen (1989) have separated the two variables and demonstrated that schooling has a nearly double effect as compared to age. This result was later confirmed by other studies (Crone, Whitehurst, 1999; Stelzl, Merz, Ehlers, Remer, 1995) as well.

Although the effect of schooling is well-known in the accumulation of knowledge, our objective is to separate cognitive effects from metacognitive ones with regard to analogical reasoning and analogical transfer. The aim was to delimit the effect of a year of schooling in the increase of operational level of analogical reasoning from the effects of chronological age. In specialty literature that deals with this topic, there are contradictory data concerning the effect of schooling on performance in tests that measure psychometric G factor. If the performance in independent culture-based tests based on analogies does not increase linearly with school age, it means that schooling has a rather metacognitive effect, more precisely children learn planning and correlation strategies as well as approaches to problems.

Objectives and hypotheses

Although the effect of schooling is well-known in the accumulation of knowledge, our objective is to separate cognitive effects from metacognitive ones with regard to analogical reasoning and analogical transfer. The aim was to delimit the effect of a year of schooling in the increase of operational level of analogical reasoning from the effects of chronological age.

On basis of previous results, we assume that schooling (integration into a formal educational system) has a greater effect on the efficiency in solving analogical problems than the level of education.

Method and procedure

Participants

A group of 70 children aged between 7-11 years (M = 8.32, sd = 2.59) have been enrolled in the study. The children were divided into 3 groups based on their experience of schooling: 6 children were unschooled, 30 children were attending school only occasionally and 34 were attending school regularly. The groups were balanced in what concerned the criteria of age and sex.

Tools

In the present study the Matrix Analogy Test (MAT), described in part 3, was administered.

Procedure

The test was administered individually and its duration was approximately 30-50 minutes for each participant. Testing took place during the month of May, 2013. The tests were administered by three experienced examiners.

Results

Table 7.
Effect of schooling, chronological age and educational level on performance in the MAT

Subtests	Factors	*B*	P
Pattern completion	Schooling	0,712	,000
	Level of schooling	0,175	,155
	Age	0,174	,129
Analogical reasoning	Schooling	0,585	0,000
	Level of schooling	0,216	0,169
	Age	-0,025	0,086
Serial reasoning	Schooling	0,536	0,000
	Level of schooling	0,305	0,051
	Age	-0,054	0,706
Spatial visualisation	Schooling	0,602	0,000
	Level of schooling	-0,159	0,384
	Age	0,047	0,779

Schooling variable (Table 7.) has a significant effect on the results of analogical reasoning subtests. Age and level of schooling have no significant effect on the results of the 4 subtests.

Discussions and conclusions

The combined effects of schooling, age and level of schooling on different types of problems have proved to be different. In more simple problems, such as pattern completion based on analogical reasoning, schooling has been found to have the greatest influence. Influence has been the weakest in tasks based on serial thinking and spatial visualization. The ability to discover the order in which items appear in a matrix and the ability to imagine what a figure will look like when two or more components are combined, are more accessible to children with lower levels of schooling, i.e. children in grades 1 and 2.

According to Ceci (1991) și Christian et al. (2001), schooled children perform better in basic intelligence tests and apparently unschooled children have much poorer results. These differences are not based on a different operational level but on lack of strategic knowledge of metacognition.

Study IV. b. Modifiability of metacognitive mechanisms of analogical reasoning and transfer

Theoretical substantiation

The results obtained in study IV a made it necessary to check the role of variables such as schooling, level of schooling and chronological age in determining the modifiability of reasoning. The program applied in this study is much more practical and as such, resembles the tests with contents integrated into everyday activities (Brovers, Mishra and Van de Vijer, 2006). Previous studies failed to demonstrate significant differences between children with and without formal schooling.

Hypotheses

In the context of samples aimed at solving analogies after a period of training/learning, the effect of schooling does not manifests itself at a significantly high level, as in the case of formal problems, but represents a positive predictor of transfer coefficient.

Method and procedure

Participants

Table 8.
*Number of participants/age and schooling **

Schooling	*7*	*8*	Total
Non-schooled	4 (1,3)	8 (4, 4)	12 (5,7)
Regularly attending	10 (6, 4)	13 (7,6)	23 (13, 10)
Total	14 (7, 7)	21 (11, 10)	35 (18, 17)

** The number of boys and girls is listed in parentheses*

Tools

We used the CATM instrument as described in Study III.

Procedure

The 3 series of isomorphic analogical problems were administered individually, pretest administration lasted for about 15 minutes per participant. Learning phase lasted much longer in non-schooled children (about 1 hour and 20 minutes), while schooled children assimilated solving strategies in 15-20 minutes. Post testing took place immediately after the learning phase and lasted 10-20 minutes on the average (regardless of the group). Taking into account the criteria imposed by us, testing occurred during May and June (so as not to be administered after a long holiday).

Results

Table 9.
Regression analysis

Variable	Pretest			Posttest			Transfer		
	B	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*
Schooling	2.31	1.88	1.12	5.76	1.50	0.87*	0.73	0.21	1.01**
Level of schooling	0.96	1.18	0.24	-0.50	0.94	-0.13	-0.25	0.13	-0.59
Age	1.43	0.89	0.24	0.55	0.71	0.09	0.03	0.10	0.06
	Schooling x Level of schooling x								
R^2	0.45			0.62			0.34		
F	8.78**			17.26**			5.41**		

**p < .05. **p < .01.*

Variance of present operation level of analogical reasoning (pretest), measured with practical samples is explained in up to 45% by the cumulative effect of schooling, level of schooling and age. Variables included in the experiment have been demonstrated to exercise the greatest influence during post testing (after the learning phase). At this stage of the solving of analogies, 62% of variance of results can be explained by factors of schooling, level of schooling and age. Transfer coefficient is influenced in up to 34% by the cumulative effects of schooling, level of schooling and age.

The highest results have been obtained by schooled children in both pretest and posttest phase ($F(2, 32)=8.78$, $p<0.001$ in pretest phase, respectively $F(2, 32)= 17.26$, $p<0.001$ in posttest phase). The transfer coefficient of schooled children was significantly higher than that of non-schooled children ($F(2, 32)=5.41$, $p<0.001$).

Discussions and conclusions

The data highlight the role of schooling which has a significant influence on transfer coefficient and posttest results. Schooled children had better results than non-schooled ones at each stage of the test (pre-and posttest) but only after learning stage results were influenced by schooling. These results lead us to the idea that learning phase was able to create a "mini tuition period" but this has an effect only if it is cumulated with regular attendance in a formal educational system. Schooled children benefited more from the induction of metacognitive strategies. Thus, the obtained results are consistent with Posner’s results (1982): schooling induces the use of strategies without affecting the operational level of the children.

CHAPTER VI.

Final Conclusions

An important conclusion on the functioning of cognitive mechanisms of analogical transfer in solving nonverbal tasks of analogy refers to the relative equality of solving time in the two main groups of coding style (colour and shape/position). This result emphasizes the similar efficiency of various styles of encoding in the elaboration of the correct response, as well as the fact that analogical transfer is accomplished using several variants of source/target information processing and the use of different solving strategies.

As such, different structures of cognitive analogical transfer mechanisms can operate within the stages of solving the analogies. Although the results in specialty literature on the topic of stages that make up the analogical reasoning process is concurrent, (Sternberg, 1997; Gick, Holyoak, 1996) the structural uniqueness of cognitive components operating within those stages cannot be sustained. There are several characteristic types of correct response elaboration and also several prevailing styles of information encoding.

Metacognitive mechanisms are important components of analogical transfer and reasoning. These mechanisms can be learned and activated by formal education, through formative instruments.

The Analogon computer program, by registering data accurately, is an instrument that can be used both for research (to identify the level of functioning of composing cognitive structures) and educational purposes.

Cognitive and metacognitive anchors of the Prompt Inventory improve performances of analogical transfer and reasoning.

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