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THE FACILITATING EFFECT OF THE HIERARCHICAL ORGANISATION OF CONCEPTS TO THE SYLLOGISTIC REASONING

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Abstract. Although intuitively tenable the impact of specific school-learned skills on syllogistic reasoning have so far received little attention. In this study recent theoretical propositions about the facilitating influence of the explicit hierarchical organisation of concepts on the syllogistic reasoning were empirically tested. Pupils in grades 10, 11, and 12 and university students were presented with two logically identical sets of syllogisms with two kinds of fantasy content: hierarchical (concerning hypothetical classification of animals from another planet) and non-hierarchical (concerning behaviour of human-like creatures). It was found that, in all age groups, the indeterminate syllogisms with the hierarchical content were solved significantly more accurately as compared to the non-hierarchical condition, while there were no differences in correct answers for determinate syllogisms. The results were interpreted in line with earlier suggestions that the school-acquired ability to envision asymmetric relations between the terms helps to detect the invalidity of indeterminate syllogisms.

Keywords: reasoning, syllogisms, pragmatic effects, concepts

1. Introduction

The traditional tasks of logical reasoning can be both strikingly easy and extremely difficult for adults as well as children. From the four possible conditional reasoning problems, *modus ponen*s (if *p* then *q*, *p*, therefore *q*) seldom invokes errors starting from six-year old children (Staudenmayer, Bourne 1977, Wildman, Fletcher 1977). However, even adults are reluctant to draw a perfectly valid conclusion from *modus tollens* (if *p* then *q*, not *q*, therefore not *p*), or are prone to make invalid conclusions with the conditional problems of the form *denial of the antecedent* (if *p* then *q*, not *p*, therefore not *q*) and *affirmation of the consequent* (*q*, therefore *p*). The amount of correct answers to the latter three tasks gradually increases with age, although adults' performance is far from perfect (see Overton 1990 for a review).

Another group of tasks of traditional logic, categorical-syllogisms, appear to be more difficult. Similarly to the conditional problems, some of the possible 64 categorical syllogisms are solved correctly by preschoolers (e.g. *All A are B, All B are C,* therefore all *C are A*) (Dias, Harris 1988, Hawkins et al. 1984), however many other syllogisms are frequently solved incorrectly. The developmental data provided for the easier subset of 28 syllogisms regarding 9-year-old children and adults indicates that children solve correctly approximately one-third and adults one-half of the syllogisms (Bara et al. 1995). Thus, both in case of conditional syllogisms and categorical syllogisms, some development seems to occur.

Several ideas about the origins of the development of logical reasoning have been suggested. According to the theory of mental models, children's deficiencies in syllogistic reasoning stem from their yet limited working memory abilities and skills in searching for counterexamples (in finding several alternative mental models for a particular syllogism) (Bara et al. 1995). Thus, according to this view, the growth of logical reasoning has nothing inherently logical about it (these are not the inferential rules that matter), instead the development is rooted in the increase of working memory abilities and knowledge base to interpret particular premises (Johnson-Laird et al. 1986).

The theory of mental logic developed by Braine (1978, 1990) takes a different route. It divides logical skills into primary and secondary skills. Primary skills consist of inferential rules that are either innate or develop very early and are available to all of us. An example of one primary inferential rule is the above mentioned *modus ponens*; it is automatic and universally obvious to all people. Secondary skills, although based on the primary skills, are considered to be the result of education and have more academic nature. The correct answers to *modus tollens* would require some secondary skills; here it is necessary to construct a longer chain of reasoning where the primary rule of *modus ponens* and the *reductio ad absurdum* rule are applied. Therefore, fallacies with *modus tollens* are frequent and they gradually diminish with the cognitive development of a child. These longer reasoning chains impose greater demands on memory and often the use of written language is necessary. Another characteristic feature of secondary skills is the requirement to accept the strategy of minimal commitment – focus is not on what the speaker means, however imprecisely and elliptically it might have been expressed (as is the case with everyday reasoning), but on what the sentence is committed to (Braine 1978). Additionally, in non-academic everyday reasoning situations people use all the information available, whereas in case of more advanced logical tasks they should compartmentalise information, i.e. use only the information contained in the premises. Hence, Braine's theory, in contrast to the theory of mental models, proposes that specific skills that are introduced in school may be the constituent factors for the development logical reasoning.

There is empirical evidence that at least some of our logical skills come from school. Cross-cultural studies conducted by Scribner (1977) and Luria (1976) revealed that people from traditional cultures, although able to reason, rejected the syllogistic tasks as such, since the compartmentalisation skill (i.e. assessing the logical structure of a task for its own sake) was not in their cognitive repertory. Several studies have established that children in modern Western cultures are very early able to set aside their knowledge and, thus, can solve easier logical tasks (Hawkins et al. 1986). However, at first the ability to compartmentalise appears in cases where the use of the earlier knowledge is not feasible, e.g. in the play or fantasy contexts (Dias, Harris 1988, Seier 1994).

To reason logically not taking into account the different conversational or pragmatic principles is more difficult. It has been ascertained that biconditional-like (*if* is understood as *if and only if)* interpretations of the conditional, where denial of the antecedent and affirmation of the consequent give valid conclusions, are evoked by different conversational comprehension processes (Braine, O'Brian 1991, Rumain et al. 1983). For instance, for the statement *If you mow the lawn, then I'll give you five dollars* the interpretation *If you don't mow the lawn, then-won't give you five dollars* seems reasonable in everyday life. Still, logically, the conditional does not allow that kind of interpretation. Politzer (1986) has presented a more general view. His conflict hypothesis argues that the development of (secondary) logical reasoning occurs in many cases due to the gradual disentangling of the conflict between pragmatic principles of everyday language use and the principles of logical reasoning. From Gricean principles of conversation (Grice 1975) it follows that the speaker should be as informative and relevant as is required by the situation. Logical analysis on the contrary, as mentioned above, rests on the principle of minimal commitment. Thus, the pragmatic principles cause the listener to make inferences not explicitly stated in the utterances. One well-known occasion is the everyday use of the word *some* not compatible with the logical meaning of the word (Newstead,1995, Noveck 2001). In everyday conversations *some … are* implies *that some others are not*, which is logically invalid, because the logical meaning of the quantifier *some … are* does not exclude the possibility that *all … are* (e.g. when someone answers to the question *Are all the cakes ready?* with *Some are*, the usual interpretation would be that some other cakes definitely are not). Politzer (1986) reviewed the vast amount of relevant psychological literature and showed that there are indeed many different cases where pragmatic laws of language use are in conflict with the logical interpretations. He proposed that these phenomena are responsible for the fallacies people make, children to a greater extent than adults, while solving the logical tasks. The logical problems where pragmatic principles are responsible for misinterpretations included the interpretation of quantifiers, understanding of the connectives, conditional problems and categorical syllogisms.

Similarly to Braine, Politzer argued that it is the effect of schooling that increases the child's ability to use the conventions of logic instead of the conventions of language. Nevertheless, neither of them has been explicit about the exact nature of the cognitive changes that schooling elicits, which would allow pragmatic interpretations of the logical tasks to be set aside. Recently, in a study by Cahan and Artman (1997) several school-learned cognitive skills were tentatively revealed which may assist the task of following the rules of logic.

Amongst them were the systematic analysis of causation (the specification of the necessary and sufficient conditions for a particular phenomenon), literal analysis of the texts, hypothetical thinking, and also the explicit hierarchical organisation of knowledge (e.g. the classification of animals). All of these tasks supposedly assist the comprehension of the "weak" asymmetric relations between the components of the sentence and the significance of the order of their presentation. In case of the conditional syllogisms, understanding of the "weak" asymmetric structure excludes the biconditional-like interpretations of the implication – children do not infer *if p then q; q, therefore p*; they can envision the possibility of *q and not p*. Causal analysis as introduced, for example, in physics classes, should smooth the grasp of this asymmetry (e.g. *If the bulb lights up, the material is a conductor, but it is not true that if it is a conductor, the bulb will necessarily light up*) (Cahan, Artman 1997). In case of categorical syllogisms, asymmetry is required for the understanding that some members of the predicate class are not included in the subject class. Symmetric interpretations of categorical syllogisms (when the possible members of the predicate class outside the subject class are not taken into consideration) are caused by the pragmatic rules of language and lead to various invalid conclusions (for example, *All A are B, All C are B, therefore All C are A*). In language, the subject of the sentence usually limits the universe of discourse (it constitutes the topic or the given information) (Harris 1952) and all the predicate values outside the subject class are irrelevant (Begg, Harris 1982, Politzer 1986). For instance, in the sentence *All people are mortal*, the word *mortal* is the focus of the sentence and it refers (from pragmatic point of view) only to the topic, that is to people. In the syllogism given above, the B's that are not A's and C's may then not be considered relevant or even existent and the conclusion *All C are A*, thus, seems valid. But the rules of logic do not allow this kind of interpretation. In logic, the universe of discourse is defined independently of the subject of the sentence, and the sentence delineates two sets in that larger superset or universe (Politzer 1986). Here, the correct interpretation requires the consideration of B's that are not A's or C's. Hence, to be able to produce correct answers it is necessary to refrain from pragmatic rules. In the example given above, one has to adopt a more analytical attitude and look at the sentence in a somewhat backward manner, also considering mortals who are not people. Cahan and Artman (1997) claimed that one of the possible means to learn how to interpret these sentences correctly, i.e. asymmetrically (*All A are B does not mean that All B are A*) is with the explicitly hierarchical organisation of knowledge, where subordinate and superordinate categories have asymmetric relations. For example, it is unlikely that children would, from the two statements *All cats are mammals and all dogs are mammals* conclude that *All dogs are cats*, because they know that there are other kinds of mammals as well. There are various cases where the set-subset relations are essential, in addition to the classifications of animals they can be found in different other conceptual systems. For instance, geometrical objects are defined on different levels of specification (e.g. *tetrahedron is a pyramid, but it is not true that pyramid should definitely be tetrahedron*). Also the classifications of chemical elements have such hierarchical relations (*iron is a metal, but a metal is not always iron*). When such clear-cut and explicit hierarchical systems are learned in school, children may gradually become able to interpret quantified sentences as referring to an independent larger superset. Then, the universe of discourse is not delineated only by the topic determined by the subject of the sentence and consequently the predicates are interpreted more in accordance with logic.

Cahan and Artman (1997) proposed that children generalise this grasp of asymmetrical interpretation of quantified sentences to other non-hierarchical contents and that this could be one way how schooling advances reasoning. However, their suggestion about the facilitating effect of hierarchical structure of concepts was merely theoretical and has not been empirically tested.

This study aims to investigate whether such effect of hierarchical concepts really exists. The simple prediction derived from the above is that syllogisms with hierarchical content would receive fewer errors than their non-hierarchical counter-parts, despite their logical equivalence. Since the failure to consider members of the predicate class outside the subject class leads to fallacious determinate conclusions from the indeterminate syllogisms (as explained above), it should be expected that the hierarchical organisation have the impact only for this group, although for comparison also determinate syllogisms are included in the experiment.

Earlier, a study carried out by Ward, Byrnes, and Overton (1990) investigated the performance on conditional reasoning problems with meaningful relations between concepts. These included, for example, conditionals with known object property relations (*If it is gasoline, then it is flammable*) and also class inclusion relations (*If it is a lizard, then it is a reptile*). They found that when there were meaningful relations between concepts the conditionals were solved more accurately. In contrast to their study, the interest in this paper is not in particular entailment relations between specific concepts, but rather on the effect of hierarchical organisation as such. For this reason, hypothetical hierarchical content was used. Namely, the premises of the syllogisms contained statements about fantasy animals from another hypothetical planet, where, as it was assumed, animals are also hierarchically grouped. Syllogisms with non-hierarchical content were about human-like creatures and here the semantics characteristic of humans was applied.

The predicate interpretation, which does not take into account its values outside the subject class, involves actually erroneous quantifier interpretation (*All A are B* is mistakenly understood as referring to identity relationships between A and B) (Politzer 1986, Roberts et al. 2001). To establish whether this incorrect quantifier interpretation is related to the fallacies made with indeterminate syllogisms, the Euler circle quantifier comprehension task, identical to the one used by Neimark and Chapman (1975), was also included in the study. It was expected that those who are prone to make incorrect conclusions from indeterminate syllogisms do not consider that quantifier *all* has both identity and subset relation interpretations. If this were the case, it would indicate that the incorrect understanding of the predicate is indeed responsible for the fallacies made with indeterminate syllogisms, and hence the explanation given to the possible effect of hierarchical content might be true.

Finally, it was hypothesised that some developmental changes may be present with respect to the influence of hierarchy. It was expected that a developmental decrease of the facilitating influence of the hierarchy of concepts might take place, and that adults will reason correctly irrespective of the content. To investigate this, participants were recruited from three high-school grades (who should generally be able to solve at least some complex invalid syllogisms accurately, but should perform worse than adults) and from university students.

2. Experiment 1

2.1. Method

Materials. All the participants received 12 categorical syllogisms in the written form in a booklet. Six of them were concerned with the content of the different groups of fantasy animals from another planet. Usually at least one of the premises had the form “one group of animals belongs to another larger kind of animals” which had the intention to stress the hierarchical relationship between these groups of animals (similarly to our general classification of animals). The other six syllogisms consisted of premises with the content of usual human activities (like watching TV or walking) of human-like creatures from another planet, there were no hierarchical relations between concepts here (see Appendix A). Both of these groups contained six pairs of logically identical syllogisms (i.e. for the logical form “*Some A are B, All C are B*” both contents were applied). Three pairs of syllogisms had the determinate correct conclusion and three were the indeterminate syllogisms to which the correct answer is *no valid conclusion*. To make the tasks easier, the pupils were not asked to make the conclusions themselves, conclusions were given and pupils were asked to evaluate their validity. For this end three possible choices were prearranged a) *the conclusion is correct*; b) *the conclusion is not correct and there is no way to make a determinate conclusion*; and c) *the conclusion is not correct, because some other conclusion is correct*. In the latter case, they had to write down their own preferred conclusion. However, the correct answer was always either a) or b) depending on whether the syllogism was of determinate or indeterminate type. The answers were coded as correct or incorrect. Pupils also had to give a very brief written explanation of their choice. These explanations were not formally analysed and the main reason for this requirement was to minimise the possibility of random guessing and to ensure that pupils actually reason while solving the tasks. In most cases the explanations were indeed given and their meaning was, with rare exceptions, comprehendible.

After the section of syllogisms, the task of the interpretations of quantifiers was presented. This task consisted of four sentences: *All A are B*; *Some A are B*; *Some A are not B*; and *No A are B* with the drawings of all possible relations between A and B. These relations are 1) A and B are identical; 2) A is a subset of B; 3) B is a subset of A; 4) A and B are partially overlapping sets; and 5) A and B are mutually exclusive sets. Participants had to select the drawings which correspond to the interpretation of the particular sentences. In most cases the sentences have several correct relations: to the statement *All A are B* the correct interpretation should include both relation 1) and 2), for *Some A are B* these are 1), 2), 3), 4), for Some A are not B 3), 4), 5), for No A are B 5).

Participants. The study had the total of 163 (31% male and 69% female) participants, 127 were high-school pupils and 36 university students. The high-school pupils included: 52 pupils from grade 10 (mean age 15.9, SD = 0.42), 31 from grade 11 (mean age 16.9, SD = 0.34), and 44 from grade 12 (mean age 17.5, SD = 0.51). The 36 university students had the mean age 21.4 (SD = 2.1). Due to technical problems not all participants received the quantifier interpretation task (total N = 126), but all age groups were nonetheless approximately equally presented. All the pupils came from the state school in the city area and generally shared a middle class background. University students were mainly the students of psychology.

Procedure. The syllogisms were presented in a booklet in the usual class settings. Before the participants began to solve the tasks a detailed written instruction sheet was given to them, the content of which was also told orally. In the instructions, it was explained that these tasks would measure their ability to think logically. With the aim of invoking a more analytical mode of thinking the following story was presented:

> *From an unknown planet we received letters with two statements in each letter about the creatures that inhabit the planet. The statements themselves are always true and your task is to draw the correct conclusions from them. Someone already has made the conclusions, but they are not always correct and we ask you to evaluate their validity. Note that in some cases, no valid conclusions can be drawn.*

It was then explained that the test consists of the tasks with two different contents: about animals who live on that planet and about human-like creatures. As for animals, it was said that they belong, like animals on earth, to larger and smaller groups (like species and families of animals) and we want to know which groups of animals belong to which larger group. Some examples about our classification of animals were given to remind that to pupils (e.g. *all predators are mammals*). Concerning human-like creatures it was simply mentioned that they are similar to humans, perhaps like Smurfs or trolls and we are interested in their behaviour.

The syllogisms were presented in two orders, in one case the tasks with human-like creatures were given first followed by the tasks about animals, in another case the sequence was reversed. Approximately half of the participants in each age group received one order and another half received the other.

2.2. Results and discussion

The means of correct answers to all syllogisms are given in Table 1. In all grades the sum of means for three indeterminate syllogisms were statistically significantly different for hierarchical and non-hierarchical syllogisms. For the grade 10 the results of Wilcoxon test were z = 3.1, N = 52, p = 0.002, for grade 11 z = 2.4, N = 31, p = 0.017, for grade 12 z = 2.5, N = 44, p = 0.012. The differences between the students' means were not significant for indeterminate syllogisms and also no differences for any age group were found between hierarchical and non-hierarchical determinate syllogisms.

Table 1. Means of correct answers to determinate and indeterminate syllogisms used in Experiment 1

Hierarchy	*Yes*	*No*	*Yes*	*No*	*Yes*	*No*	*Yes*	*No*
Determinate syllogisms	*IabAbc*		*AbaIbc*		*IabEbc*		*Sum of means (SD)*	
Grade 10	*.77*	*.80*	*.73*	*.69*	*.61*	*.81*	*2.12 (0.83)*	*2.3 (0.83)*
Grade 11	*.90*	*.81*	*.71*	*.81*	*.74*	*.81*	*2.35 (0.70)*	*2.44 (0.80)*
Grade 12	*.86*	*.89*	*.75*	*.54*	*.79*	*.84*	*2.41 (0.76)*	*2.27 (0.76)*
Students	*.97*	*1.00*	*.83*	*.88*	*.83*	*.92*	*2.64 (0.64)*	*2.81 (0.47)*
Indeterminate syllogisms	*AabIcb*		*IbaIcb*		*AbaOcb*		*Sum of means (SD)*	
Grade 10	*.69*	*.65*	*.57*	*.32*	*.71*	*.50*	*1.98 (0.85)*	*1.48 (0.85)*
Grade 11	*.84*	*.75*	*.77*	*.50*	*.87*	*.68*	*2.48 (0.77)*	*1.94 (1.04)*
Grade 12	*.80*	*.65*	*.57*	*.50*	*.84*	*.64*	*2.2 (0.85).*	*1.8 (0.88)*
Students	*.97*	*.97*	*.67*	*.67*	*.97*	*.94*	*2.61 (0.60)*	*2.58 (0.60)*

The logical form of the syllogisms is coded according to the order of the terms (e.g. abcb) and the quantifiers, where A= "all", E= "no", I= "some," and O= "some not".

The order of presentation had an effect only for grade 12, where the amount of correct answers was significantly higher for indeterminate syllogisms with non-hierarchical content when the hierarchical syllogisms were presented first (Mann-Whitney U = 123, p = .006). This finding possibly indicates that older pupils may have been able to learn to detect the invalidity of the given conclusions in case of non-hierarchical syllogisms when they had the chance to solve the hierarchical syllogisms first.

The Kruskal-Wallis analysis of variance for grade differences between high-school pupils showed the main effect only for indeterminate syllogisms with hierarchical content H(2, 127) = 8.26, p = 0.016 and marginal significance for non-hierarchical indeterminate syllogisms H(2, 127) = 5.66, p = .059. Differences between separate grades were significant only between grades 10 and 11 with both hierarchical and non-hierarchical indeterminate syllogisms (Mann-Whitney U = 524, p = .008 and U = 614, p = .004). Differences between all high-school pupils taken as one group and university students were significant with all four groups of syllogisms: with determinate hierarchical U = 1686, p = .015, with determinate non-hierarchical U = 1640, p = .01, with indeterminate hierarchical U = 1548, p = .003 and with indeterminate non-hierarchical U = 1073, p<.0001.

The results of the quantifier interpretation task were very similar to the study conducted by Neimark and Chapman (1975), who used exactly the same measures, and since the quantifier interpretation itself is not the primary interest of this study these results are reported only briefly. The means separately for grade level are presented in Table 2. There were two kinds of errors, first, most subjects did not consider that *some are* does not exclude the possibility that *all … are* and for that reason did not mark the corresponding drawings (e.g. *some … are* has four possible set relations, including identity relation between two sets). The other mistake was the failure to mark for the statement *All A are B* both identity relation and the relation of A as a subset of B. This error was characteristic to 17% of the participants. No errors were made with respect to the sentence *No A are B.*

Table 2. Means of correct selections of drawings in quantifier interpretation task used in Experiment 1

	Grade 10 (N = 44)	*Grade 11 (N = 24)*	*Grade 12 (N = 44)*	*Students (N = 32)*
Sentences				
All A are B (2)	*1.67*	*1.68*	*1.77*	*1.84*
Some A are B (4)	*1.46*	*1.52*	*1.77*	*1.86*
Some A are not B (3)	*1.29*	*1.44*	*1.57*	*1.81*

The digits in parentheses refer to the maximum number of correct selections

More relevant is the pattern of correlations between quantifier interpretation and the syllogistic task. Since the university students showed a ceiling effect with syllogisms, their data is excluded from the correlational analysis. As is shown in Table 3, significant, albeit small, correlations were found singly between the *all…are* quantifier comprehension and indeterminate syllogisms. This is in accordance with the proposition made above that specifically for indeterminate syllogisms the knowledge of the fact that *All A are B* does not mean that *All B are A* is crucial and that both identity and subset interpretations must be considered to obtain the correct solutions for these syllogisms.

Table 3. Correlations (Kendall τ) between correct answers to syllogisms and the quantifier interpretation of the high-school pupils in Experiment 1 (N = 93)

Syllogisms	*Hierarchical*		*Non-hierarchical*	
	Determinate	*Indeterminate*	*Determinate*	*Indeterminate*
Sentences				
All A are B	*.10*	*.26***	*.04*	*.15**
Some A are B	*.04*	*.09*	*.03*	*.00*
Some A are not B	*–.03*	*–.04*	*–.09*	*.05*

*p<.05 **p<.001

Generally, the results of the experiment are very consistent – all the indeterminate syllogisms were solved more accurately with the hierarchical content, at the same time no pattern emerged from the answers to determinate syllogisms, which is the predicted outcome. Although the amount of accurate responses increased with age and high-school grades for all syllogisms, the numerical difference between the sums of means for hierarchical and non-hierarchical syllogisms remained approximately the same (0.4–0.5 in all cases).

The results of the experiment were ambiguous concerning students. They showed a ceiling effect in two out of three of indeterminate syllogisms, while in one case the proportion of correct answers was equally low for both hierarchical and non-hierarchical condition (.67). These results do not permit to make conclusions about whether students do not experience the influence of the semantic differences. It is possible that the equal performance in one syllogism was due to chance. To solve this issue, another set of more complex syllogisms was presented to students.

3. Experiment 2

3.1. Method

Materials and procedure. Because the previous experiment demonstrated that the facilitating effect of hierarchy had no impact for determinate syllogisms, only indeterminate syllogisms were used. Four syllogisms, with the supposedly more difficult logical structure were offered (Appendix B). The relative difficulty of syllogisms was assessed on the basis of the data for all 64 syllogisms provided by Johnson-Laird and Bara (1984). In all other aspects the materials and procedure were identical to Experiment 1, with the only exception being the absence of the task of the interpretation of quantifiers in Experiment 2.

Participants**.** 22 psychology students (mean age 22, SD = 3.3) drawn from the same sample as in Experiment 1 took part.

3.2. Results and discussion

The means of correct answers for hierarchical syllogisms were .73 (AabIbc) and .68 (IbaAcb) and for non-hierarchical syllogisms correspondingly .59 and .23. The sums of means were for hierarchical syllogisms 1.42 (SD = 0.8) and for non-hierarchical 0.83 (SD = 0.72) the difference between them being statistically significant (Wilcoxon $z = 2.67$, $N = 22$, $p = .008$). The differences of the means depending on content type were even larger than in earlier data from pupils. This fact clearly demonstrates that the effect of interest is not solely developmental and that with more complex tasks adults are also sensitive to it.

4. General discussion

The two experiments conducted revealed that an explicit hierarchical system of concepts (that is, hypothetical classification of animals) reduces the number of invalid conclusions from indeterminate syllogisms. This outcome has several implications. It is intuitively quite reasonable to believe that school-learned knowledge and skills should improve the logical reasoning. Braine's (1990) distinction between primary and secondary skills puts a vast amount of logical tasks into the sphere of purely academic activities; they are both learned and used mainly in school or in other academic contexts. Nevertheless, precise analyses of the factors of schooling that are responsible for the development of advanced logical reasoning have been left undone. The reasons for this state of affairs are objective – the processes involved are complex and rather different school-subjects may contribute (from classes of literature to the science ones). Braine noted that the inducement of secondary logical skills is actually a quasi-academic process, because the logical reasoning skills are introduced only indirectly, inside a particular domain in the form of specific analytical skills (e.g. literal analysis of the texts). However, some clarification of the issue should be possible and the notion of explicit hierarchical structure of school-learned concepts may be the appropriate candidate for this work.

Undoubtedly, not only scientific concepts are hierarchically organised; the semantics of language is itself hierarchical. Nevertheless, its hierarchical sub- and superordinate categories are not unambiguous and all semantic aspects are subject to different interpretations. For instance, the superordinate class furniture has subordinate categories chair and table, yet it is easy to find interpretations to the apparently illogical statement *All tables are chairs* (e.g. one can sit on both), while the analogous statement with school-learned concepts *All circles are squares* seems quite senseless. Indeed, many concepts learned at school are defined and have manifestly delineated meanings, the possible semantic relations (including hierarchic) between them being cognitively less ambiguous.

So, in everyday language, the clear-cut relationships between sub- and superordinate categories are not always stressed and sometimes they are even rejected. Politzer (1986) gave the following example of a usual dialogue:

> *Father: (to child, pointing at a person at some distance) Who is coming?*
> *Child: A lady.*
> *Father: No! It is not a lady! It's Mummy!*

In this particular case, it is pragmatically not reasonable to use superordinate category instead of the subordinate (although it is completely logical), because the most appropriate level of the hierarchy must be used (basic-level term). Thus, the child here is patently instructed to discard the class inclusion relationship in favour of pragmatic relevance. Politzer (1986) noted also that in mathematics classes children usually find it difficult to understand that a square can be validly designated by a higher item in the hierarchy, such as rectangle. It is not typical for the everyday language children have acquired earlier to use asymmetrically synonymous words like these, this has to be the effect of schooling. The well-defined concepts learned in school gradually organise knowledge into different methodically organised hierarchical systems. As explained above, when these clear-cut conceptual systems are acquired, the interpretation of the sentences does not depend on the subject of the sentence (i.e. given information or topic by which the universe of discourse is ad hoc defined) with its potentially narrowing effect on the interpretation of the predicate. Instead, a broader conceptual system is activated and therefore the members of the predicate class outside the subject class are also considered, which is in line with the accurate logical interpretation.

This explanation is strengthened by the quantifier interpretation task used in the study. The only significant correlations found were between the participants' correct interpretations of the quantifier *all … are* and the performance with indeterminate syllogisms. It is obvious, that only if the two interpretations of this quantifier – both identity and subset (where the subject term is the subset of the predicate term) relations are taken into account, the invalidity of the indeterminate syllogisms can be detected. However, the quantifier interpretation task alone can hardly be all there is to tell about the solving of syllogisms (Roberts et al. 2001). It measures merely the understanding of a single premise, while syllogistic inference can be made only when two premises are integrated together and analysed. Therefore, the evidence provided by this measure is only circumstantial, but nonetheless, it is in the predicted direction.

There is another issue – the issue of the generalisation of this skill. Cahan and Artman (1997) presumed that with the grasp of the asymmetry of the statements this ability generalises to logical tasks with non-hierarchical content. This study was not designed to confirm or refute this claim; it had merely the intent to show that hierarchical organisation as such has the facilitating effect. However, in one case (grade 12) pupils who received the hierarchical syllogisms first, also performed better with non-hierarchical indeterminate syllogisms, which actually may hint to the possibility of quick learning. Yet in contrast, it was found that in the case of more complex syllogisms university students also benefited from the hierarchical organisation, which leaves the question of development open. Generally, the interpretational difficulties which stem from pragmatic laws of language should decrease with age but do not disappear completely (Politzer 1986). So, this result was not unexpected and is not contradictory to the idea of gradual acquisition of reasoning with the help of hierarchically organised concepts. However, more complex studies should be conducted, possibly, teaching experiments where the pupils are first instructed to solve the syllogisms with the hierarchical concepts, with the expectation of gradual increase of correct responses to all contents.

Finally, there is one other explanation of the results in this study, which comes from the theory of mental models (Johnson-Laird et al. 1992). This theory claims that syllogistic reasoning is based on the construction of different quasi-imaginal mental models to the set of given premises. Here it is crucial to consider all the possible models and search for counterexamples. The semantic organisation of the premises may make the accessibility of counterexamples more available. Bucci (1978) showed that both adolescents and adults produce more correct responses to the indeterminate syllogism *All A are B, X is B; Is X A?* which had broad predicate terms (e.g. *all football players are strong*) as opposed to narrower predicate terms (*all oak trees have acorns*), because in the former case the possibility of people who are strong and are not football players comes easily to mind, while the acorns are characteristic singly to the oak trees. Recently, the importance of the organisation of semantic memory has been stressed (Markovits et al. 1998; Markovits, 2000). The model developed by Markovits and his colleagues predicts that when counter-examples are more available in the reasoner's long-term memory, then a greater amount of correct solutions would follow. The premises provoke specific semantic activation patterns in a person's long-term memory, which either include or do not include the appropriate counterexamples and this can be the basis for many semantic differences in logical reasoning. The results of the current study could easily be interpreted in this light. Although the semantics utilised was hypothetical, its general set-inclusive nature may have also been able to highlight counterexamples, that is, alternative models to the particular syllogism. For instance, when it is said that *all red-tails belong to the ear-snouts' kind* the hierarchic organisation activates the idea that there exist ear-snouts who are not red-tails, and corresponding mental models can be constructed. In any case, what Markovits' suggestions have in common with the ideas elaborated in this study, is that the semantic organisation of knowledge should receive more attention by the researchers in the field of logical reasoning.

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Appendix A

Translation of syllogisms used in Experiment 1

Hierarchical content	Non-hierarchical content
Determinate syllogisms	
IabAbc	
Some big-toothed belong to the hairy-ears' kind All hairy-ears have green noses Conclusion: Some big-toothed have green noses	Some dorfs like to walk at nights Those, who like to walk at nights, are smart Conclusion: Some dorfs are smart
AbaIbc	
All animals of red-tails' kind are quick runners Some red-tails have large ears Conclusion: Some animals with large ears are quick runners	All samsams have big noses Some samsams are redheads Conclusion: Some redheads have big noses
IabEbc	
Some brown-furs belong to the purple-stomach kind No purple-stomach can fly Conclusion: Some brown-furs cannot fly	Some nimones have beards No one who has beard eats ice-cream Conclusion: Some nimones do not eat ice-cream
Indeterminate syllogisms	
IabAcb	
Some animals of red-tails' kind have long legs All ear-snouts have long legs Conclusion: Some ear-snouts belong to the red-tails' kind	All samsams like to watch TV Some clever beings like to watch TV Conclusion: Some clever beings are samsams
IbaIcb	
Some big-toothed are quick runners Some green-backs belong to the kind of big-toothed Conclusion: Some green-backs are quick runners	Some dorfs have big hats Some redheads are dorfs Conclusion: Some redheads have big hats
AbaOcb	
All flat-heads eat meat Purple-stomachs do not belong to the flat-heads' kind Conclusion: Purple-stomachs do not eat meat	All nimones have big moustaches No sportsman on that planet is a nimone Conclusion: The sportsmen on that planet do not have big moustaches

Appendix B

Translation of the syllogisms used in Experiment 2

Hierarchical content	Non-hierarchical content
AabIbc	
All red-tails belong to the hairy-ears' kind Some hairy-ears have green noses Some of those, who have green noses, are red-tails	All dorfs like to walk at nights Some of those, who like to walk at nights, are clever ones Conclusion: Some clever ones are dorfs
IbaAcb	
Some big-toothed are quick runners All green-backs belong to the kind of big-toothed Conclusion: Some green-backs are quick runners	Some ribules are redheads All of those, who wear hats, are ribules Conclusion: Some of those, who wear hats, are redheads