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PERSONAL EXPERIENCE AND SOCIAL MESSAGE: "SECOND-HAND" KNOWLEDGE IN COGNITIVE DEVELOPMENT

Cognitive development is viewed here as a co-action of two essential factors: Piaget's factor (bottom-up processes leading from procedural to declarative forms of representation) and Vygotsky's factor (top-down processes leading from declarative to procedural forms of representation). The continuous interplay between the two factors and integration of their results (certain cognitive structures) are regarded as an essential condition for a successful development process. In the case of lack of such integration, disfunctional scholastic knowledge emerges. These hypotheses were corroborated in the experimental simulation of microdevelopmental processes in the task of mastering a new (artificial) domain. The results have direct reference to education.

1. An outline of the theoretical model

1.1. Piaget's factor and Vygotsky's factor in development.

In this study some basic questions of cognitive development are reconsidered from a new perspective of knowledge representation theories. It is argued that what Piaget and Vygotsky described in their classical conceptions now can be given a new interpretation and considered as two fundamental factors that contribute to the developmental process. We propose to call them "Piaget's factor" and "Vygotsky's factor" respectively.

Piaget's factor is rooted in the agent's direct experience. Knowledge derived from experience is gradually elaborated in the course of development and finally forms cognitive structures of high complexity, abstractness, etc. We claim that this process can be described as a transition from procedural to declarative type of knowledge representation. At first, all knowledge is implicitly embedded in goal-oriented action schemas or procedures. From these, in steps described by Piaget and contemporarily by Karmiloff-Smith (1979, 1985, 1986), J.Mandler (1981, 1983), Nelson (1981, 1986) and others, different portions of knowledge are derived and rewritten in the form of explicit declarative units of representation that, in turn, serve as data for general (but domain specific) operations in

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cognitive processing. In this manner complex conceptual structures are gradually constructed. Piaget's factor is responsible for "bottom-up" developmental processes. It leads from the individual's direct experience to highly elaborated mental constructions which can be verbally exchanged with others and may eventually enrich the common culture and socially accumulated knowledge.

However, there exists a second type of developmental process, complementary to the one above, namely, Vygotsky's factor. This factor is responsible for reverse "top-down" processes. It starts with verbally transmitted knowledge, already elaborated by other agents. Initially it can be represented in the mind only in declarative form. Then it is reorganized and rewritten into more simple and concrete structures, closer to experience and action (compare J. Anderson's ACT model, 1982, 1983). In other words, Vygotsky's factor leads from declarative to procedural forms of representations of the same portions of knowledge. In this way, socially accumulated knowledge may be used and verified in an individual's experience.

1.2. The role and mutual interdependence of two factors

In our conception Piaget's factor is given a privileged role: in ontogenesis it appears earlier (preverbal stage) than Vygotsky's factor and provides the essential basis for the latter's function. Its adaptive value for the individual is also greater than the value of Vygotsky's factor: it establishes direct contact between cognitive structures and its main subject - the agent's real experience. Such contact is a *sine qua non* condition for physical survival, whereas the role of Vygotsky's factor - enabling the individual to join in the culture and profit from socially accumulated knowledge, although also very important, is not crucial for her/his very existence. Therefore Piaget's factor is expected to be fairly independent and to have comparatively greater ability to resist outer disturbances or to compensate them if they occur. Vygotsky's factor is more open to influence, in particular it depends strongly on the results (or lack of them) of the operation of Piaget's factor.

The emerging outline of our model of cognitive development strongly stresses the continuous interplay between these two factors and integration of their results (i.e., certain structures of representation). In our model, such integration is regarded as an essential condition for a successful developmental process.

1.3. Scholastic knowledge and natural knowledge

The role of integration is important in that it provides continuity and mutual communication between the highest and the lowest levels of mental representation of reality: between the socially influenced, verbalizable conceptual system, on the one hand, and very simple, concrete, non-verbal and even - maybe - unconscious action procedures originating in the agent's immediate experience, on the other. If cognitive structures are lacking such integration, certain disturbances - here called "scholastic knowledge" - may occur.

Scholastic knowledge is defined here as declaratively represented knowledge that has been acquired from external verbal messages (via Vygotsky's factor) and not integrated with any procedural structures. Only the procedural base could make such an extraneous declarative knowledge meaningful to the agent with respect of her/his real experience. However, a scholastic structure of knowledge is lacking this kind of "roots"; it is, so to speak, suspended in mid-air. Thus it has no effect on the agent's real action and no actual adaptive value for him/her. Information processing based on scholastic knowledge is always reproductive (never creative) and does not reflect specific properties of the individual's cognitive apparatus. This knowledge was previously derived from other agents' experiences and elaborated by them in a verbalizable form. It may implicitly contain different elements of their particular cognitive perspectives (goals, values, standards, preconceptions, individual features of information processing, etc.) that are incompatible with the present agent's perspective. Therefore it may also be called "second-hand knowledge". Yet it is often retained in memory because of external, social pressure (e.g., the formal power of school over the pupil) and used only in particular situations (in our example - in exams: after passing them the scholastic knowledge will be immediately forgotten). The adaptive value is tied to the very fact that the agent possesses this knowledge, not to its content.

Scholastic knowledge arises when externally elaborated "second-hand" knowledge, carried by Vygotsky's factor, cannot be integrated with the agent's own knowledge arising from her/his experience by means of Piaget's factor. This may occur when the agent had no previous experience in a given domain or when knowledge obtained from that experience is incompatible with the knowledge carried by the verbal message. In other words, scholastic knowledge emerges in situations when, in a given field, Vygotsky's factor operates prior to Piaget's factor and when the two factors bring mutually incompatible results.

The opposite of scholastic knowledge is natural knowledge - any cognitive structure developing in accordance with the postulated sequence: Piaget's factor with its procedural base first, and only then Vygotsky's factor with its declarative structures. There are two ways of natural knowledge development. The first takes place when the procedural base spontaneously develops into declarative forms without Vygotsky's factor support (as Piaget had described it). In the second, natural knowledge may arise as a result of the integration of socially elaborated and verbally transmitted knowledge with the knowledge originating from the agent's individual experience (as postulated by Vygotsky). In any case, natural knowledge arises if and only if the procedural base had existed prior to the formation of the declarative representation and they both have been integrated into one integral procedural-declarative structure.

2. Testing the theory: The experiment

In the empirical part of this study the main theses and some specific predictions of the model were tested experimentally. In the experiment the developmental processes that have been theoretically attributed to Piaget's factor and to Vygotsky's factor were simulated.

2.1. Material

In the course of the experiment 38 subjects, age 18-22, were confronted with the task of mastering a new cognitive domain. The artificial "reality" was introduced by a computer game and by the corresponding educational program - both had been written specially for the needs of this research. The "reality" consisted of 36 fantastic animals (exemplars of 6 "species", forming a complex "taxonomic hierarchy"), living in a "forest". They were given particular characteristics, ways of behavior and specific type of interaction with the player. They also had their specific place in a complex "taxonomic hierarchy".

2.2. Independent variables: conditions for the (micro)development of the structures of representation

Any knowledge about the "world" was acquired by subjects in one of the two following ways:

* directly experiencing the "world" while playing the game, or
* receiving extraneous verbal description of the "world" through the computer educational program.

It was assumed that the knowledge about "the world" acquired through playing the game was at the moment represented procedurally, whereas the knowledge transmitted by the educational program was represented declaratively in the subjects' cognitive structures. During the course of the experiment these primary types of representation could develop into different forms.

All groups passed both kinds of training, but in a different sequence:

* procedural - declarative (first the game, then the educational program), or
* declarative - procedural (the educational program first, then the game).

Thus, the SEQUENCE of the two types of representation formation was the first independent variable (dichotomous) in this experiment.

The second variable was the CONSISTENCE of the two types of training or - in other words - the "truthfulness" of the description of "the world" given in the educational program ("taxonomy", animal characteristics, etc.) as compared to the game. Two formally equal (i.e. equally long, complex, reasonable, etc.) versions of the educational program were used: "true" and "false" with respect to the content of the game. Actually, both descriptions were equally sensible. The only difference between them was that the game was based on one of them, and not on the other.

Thus the variable CONSISTENCE had two values:

* "+", i.e. the contents of the two types of training were consistent with one another, and
* "-" , i.e. the contents of the two types of training were inconsistent.

Formally, there was also a third independent variable, i.e., TIME - created by the repeated measures of the dependent variables (see below).

2.3. Experimental groups

The combination of the two values of each of the two independent variables gave four sets of conditions and four experimental groups (see Table 1), in which - according to the model - the integration of the two factors was either promoted (first group) or suppressed in various ways (the remaining three groups). Therefore, we expected the emergence of natural knowledge in the first group and emergence of different types of scholastic knowledge in the three others. The number of subjects was 10 for groups I and II, and 9 for groups III and IV.

Table 1. Characteristics of the experimental groups

Sequence	Consistency	
	true description (+)	false description (-)
game first	Group I	Group III
educational program first	Group II	Group IV

2.4. Dependent variables: the emerging representation of the "world"

The developing representation of "reality" was the dependent variable. Three aspects were measured:

- procedural competence (operationally it was the score in a game),
- declarative competence (measured by the score obtained in the short test built-in as a part of the educational program),
- integration of procedural and declarative structures of representation (the indicator: performance on an independent task that required the existence of integrating links between procedural and declarative knowledge structures).

This third measure was a bit more complex and needs to be explicated. An independent task was a classification technique, in which 36 objects (pictures of animals) were repeatedly sorted by subjects according to their own rules. We assumed, on the basis of our theoretical model, that a task of this kind cannot be solved without at least minimal integration of procedural and declarative structures of representation. The result of the classification task (obtained by the cluster analysis) had two parameters:

– complexity (computed accordingly to R. Zajonc's formula for cognitive complexity). This indicator informs about quantitative aspects of integration. When its value equals zero, the subject's inability to solve this task is suggested. It means that no integration of procedural and declarative structures of representation have taken place. The higher the value of complexity, the wider the range of integration of the two types of knowledge representation;

– adequacy (operationally it was Pearson's correlation between two matrices of distance: one obtained from the individual subject's result in the task and the second being the standard based on the content of the game/educational program). This index informs about the qualitative aspects of the integrated knowledge structure of non-zero complexity. The higher its value, the more accurate the reflection of the content of learning in the subject's knowledge structures.

As we stated in the theoretical model, Vygotsky's factor depends in its activity on the Piaget's factor results. Therefore we expected group I to have higher scores in declarative competence and in the classification task than the other three groups. The differences between groups should increase in the course of the experiment. As far as the procedural competence is concerned, we expected that all differences between groups, if they occur at all, would decline in the course of the experiment, because Piaget's factor should remain relatively unaffected by external disturbances and by the operation of Vygotsky's factor.

2.5. Procedure

Subjects from every group had two individual training sessions (1 hour each): playing the game and learning with the educational program. They were given a short instruction by the experimenter and were left with the computer (the experimenter remained accessible for them all the time, but did not intervene nor answer any questions except formal and organizational). The measurements of all dependent variables were taken immediately after each session as well as after a delay of about two weeks.

There was also an additional measurement of integration (the classification task). After both training sessions and the second measurement subjects were "severely" informed (equally in all groups) that their last classification task was solved "incorrectly".

Figure 1. Procedural competence (scores in game)

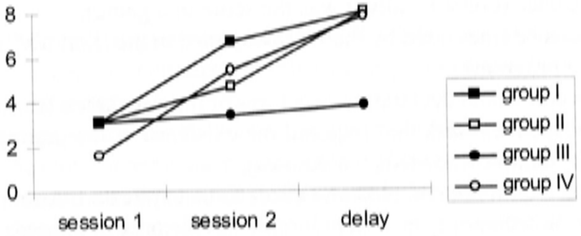


Figure 2. Declarative competence (scores in knowledge test)

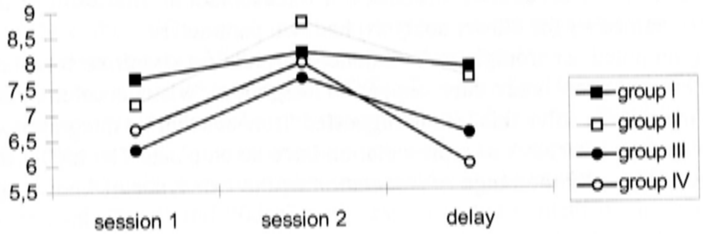


Figure 3. Complexity as a parameter of the classification task result

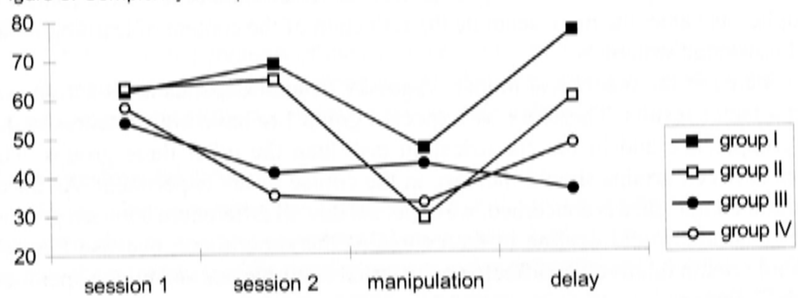
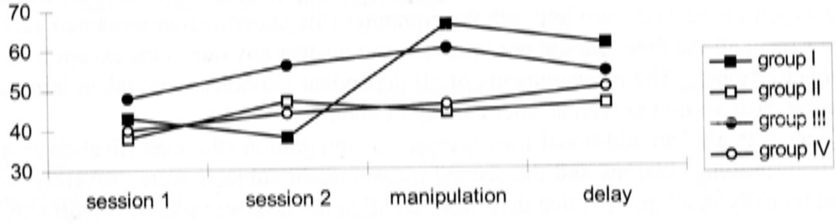


Figure 4. Adequacy as a parameter of the classification task result



They had to learn something during this experiment - said the experimenter - and it should be visible in their classifications, so they ought to do it once again. This manipulation (debriefed carefully after this measurement) changed completely the instruction for the classification task — previously free choice and individualism were stressed. The aim of this intervention was to make sure that the knowledge from the training sessions was really used by subjects in this task and to catch possible differences between this knowledge record and the subjects' "private outlook" on the "world".

The full procedure of the experiment was complex and will not be discussed here in detail. The microdevelopmental changes in representation structures were traced as well as the retention of knowledge in memory. We analyzed over 50 working variables, indicating different aspects of the retained cognitive structures (for more complete description see Stemplewska, 1996).

The experimental design was a three-factor multivariate model with repeated measures within one factor (TIME). The data were analyzed using multivariate analysis of variance (for some detailed problems principal components analysis was additionally used).

3. Results

3.1. The empirical status of the concepts of Piaget's and Vygotsky's factors

The results generally corroborate our model. It appears (Fig. 1) that procedural structures of Piaget's factor remained respectively unaffected by our experimental manipulations (no significant differences in game scores among the groups). Only the effect of TIME was statistically significant in relation to procedural competence: showing the improvement of scores during the training sessions ($F=6.42$, $p<.02$) and even after the delay ($F=8.62$, $p<.01$), suggesting the reminiscence effect. Learning by Piaget's factor processes did not follow the well-known learning rules (reflected by the classic learning curve). Procedural structures were very well retained in memory and even the regular reminiscence effect was observed. Thus the hypothesis that Piaget's factor is "proof" against external influences and builds stable retentive structures seems confirmed.

The curve formed by the measures of declarative competence looked quite different: it was the classical learning curve with its characteristic breakdown at the beginning of the forgetting phase (see Fig.2). The experimental effect of the TIME factor was significant (improvement in training sessions: $F=56.6$, $p<.001$; forgetting during the delay: $F=8.62$, $p<.01$). Group differences in declarative competence caused by the experimental factors were sharp and even deepened with time. The influence of the CONSISTENCE factor on declarative competence could be seen from the beginning of the experiment (training: $F=8.81$, $p<.01$; delay: $F=8.62$, $p<.01$). The factor of SEQUENCE added its influence in the period of delay: weak tendency to a better retention of knowledge in groups that started from the game was observed (delay: $F=2.99$, $p<.09$). This tendency was regularly observed in several fairly independent working variables, so we mention it although it is not statistically significant.

Changes in time were not observed in the parameters of the classification results. There was no characteristic diminishing of scores nor reminiscence effect with regard to complexity nor to adequacy. The patterns of scores in time (see Fig.3 and 4) may be considered as intermediate between patterns characteristic for procedural and declarative competence. Considering the fact that in the classification task we expected some integration of structures and processes of Piaget's and Vygotsky's factors, this result seems understandable.

Therefore we have empirical support for the model thesis that procedural and declarative structures - or structures constructed by Piaget's factor and Vygotsky's factor - have quite different qualities: they show different patterns of developing in time and of being influenced by external conditions. When an agent tries to integrate the activity of the two factors - the results show some intermediate patterns. These patterns constitute some empirical evidence that may be tied to the concepts of Piaget's and Vygotsky's factors, and their integration seems to be something more than a theoretical fiction. There are several interesting questions and interpretations that can be posed about these results, but they exceed the scope of this paper (for further discussion, see Stemplewska, in press).

3.2. Scholastic knowledge

The expectations regarding natural knowledge structures developing in the first group (where the model conditions for integration were met) and scholastic knowledge emergence in the other three groups, were also fulfilled. The first group has shown the highest competence in all tasks, whereas different kinds of distortions occurred in the remaining three groups. Most contrasts between groups were statistically significant on the level of .05 (excluding the procedural competence scores); they show the I>II~III>IV pattern of differences among the experimental groups.

As we expected, the SEQUENCE of the procedural and declarative training and the CONSISTENCE of their content exerted an influence on the agent's ability to integrate representation structures emerging in these conditions. The CONSISTENCE factor influenced complexity (quantitative aspects of integration): in measurements immediately after training sessions and after the delay groups with consistent training produced more complex results than the other two groups ($F=6.42$, $p=.02$) . This means that in the same task they used a wider range of procedural and declarative knowledge structures simultaneously, in a coordinated way. However, when we look at the adequacy scores, it appears that this may not be the same knowledge that was learned during the experiment. Only after the additional manipulation, in which using the learned knowledge was explicitly demanded, did the scores of adequacy jump up ($F=4.64$, $p<.05$) and remain high also after the delay (and debriefing of manipulation), but not homogeneously in all groups. Here the effect of SEQUENCE appeared crucial: the ability to adequately reflect the learned knowledge was greater in groups which started from gaining personal experience with the game and only then received the verbal message (the tendency in manipulation: $F=3.11$, $p<.09$ developed to its full effect during the delay: $F=4.42$ $p<.05$). At the first moment, this manipulation also caused a simultaneous tendency to rapidly decrease the complexity, especially in groups that had generated very complex results earlier ($F=3.12$, $p<.09$). However, after the delay these two groups returned to their high complexity level (the effect of CONSISTENCE described above).

It is important that all groups achieved non-zero results in the knowledge test (declarative competence). Therefore we can assume that all of them had some representations of knowledge verbally learned in this experiment. However they seem not to be able to use that knowledge along with the procedural knowledge (as was obvious in the case of group II and IV in the classification task), thus we may call this knowledge scholastic.

In the third group some unexpected events occured. We expected that having some procedural knowledge derived from direct experience in a "world" (via the game) would make the subjects from this group less susceptible to the "false" message of the educational program, coming in the next training session. However, it appeared that group III accepted the verbal message ("false"!) more than any other group. The development and use of the knowledge derived from personal experience was inhibited by "successful" integration with the external verbal knowledge, which was in conflict with the first. This may be the reason why the third group - the only group in this experiment - did not improve its procedural competence. (This last thesis is only hypothetical: there was a great within-group variance in game scores in this group, so the difference between group III and others is not significant, although it is clearly visible in Figure 1. We will not discuss this problem in detail here.)

All the evidence obtained in our experiment seems to point to procedural knowledge as a basis which promotes declarative knowledge reception. These results do not contradict our model: on the contrary - in this light an even more extreme version of it can be acceptable.

3.3. Interpretation of group results in school metaphor

The first group was the only group that produced results which were complex and adequate at the same time. In the school metaphor this group represents the type of "gifted pupil": it is good in knowledge tests (declarative competence), deals well with different "real" tasks (procedural competence), and integrates verbally acquired knowledge with the knowledge derived from personal experience. Although it has a very original "private view" on the "world" (low adequacy and high complexity in first classifications), it is also able to use the learned knowledge correctly in a productive task if it is demanded (high adequacy and still rather high complexity in the last two classifications). The conditions of learning that we created in this group seem to be adequate for the school setting.

The second group in the school metaphor may be regarded as the type of "studious pupil". He is good in knowledge tests; he is able to deal also with the "real world" (game), but the two types of competence remain separate. When suddenly the "studious pupil" faces the task of their productive integration - he is helpless. He can generate a complex result based on his personal experience, but it has nothing in common with the learned knowledge. He is not able to use the newly learned knowledge in a novel, productive way: his only response to manipulation in our experiment was the dramatic decrease of complexity without a corresponding increase of adequacy in the results.

The reverse situation was observed in group III. The classifications made by this group were highly adequate even before manipulation, when free choice and individualism were recommended, and remained so until the end of the experiment. This group might be compared to "victim of indoctrination" type of pupil. His "private outlook on the world" is so much dominated by the school's verbal message that not only the agent is guided by it in the novel task, but also the development of his procedural knowledge may be handicapped. This last hypothesis is not sufficiently supported by the data. Yet, if it will appear true, such learning conditions as we created in the third group may be very unfortunate for individual development and even may potentially be dangerous in the hands of manipulators.

The fourth group was lacking complexity as well as adequacy. The situation here was similar to that in the second group, but all scores were lower. We may compare this group to the type of " dull pupil" who practically deals well with "the world", but in school tests gets low scores and is not able to use school knowledge in productive ways.

All the described effects and differences were invoked by the experimental manipulations. It is especially important to state that all the results and our interpretations ("gifted" and "dull pupil" etc.) were completely determined by the experimental conditions and not by any permanent characteristics of the subjects of our experiment, in particular - not by their intelligence. Intelligence was controlled in the experiment (additional measurement with Raven's test after all sessions and the delay) and statistical tests gave no support to the hypothesis that it may differ across groups.

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