Individual and situational variability in cognitive development

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Individual and Situational Variability in Cognitive Development

Anik de Ribauipierre and Laurence Rieben

Faculté de Psychologie et des Sciences de L’Education
Université de Genève

The purpose of this article is to argue that individual differences should be taken into consideration when suggesting a model of cognitive development. Hence, a multidimensional perspective should be adopted, in which several underlying, independent processes are considered to co-determine performance; this leads to the hypothesis that different developmental paths can exist for different types of subjects. A brief review of how individual differences have been dealt with in developmental psychology is first provided. Then, a three-phase longitudinal study is presented as an empirical illustration. In the first phase, a sample of subjects ranging in age from 6 to 12 years were examined with eight Piagetian tasks. In the second phase, the same subjects were examined again 3 years later with the same tasks. The results from the first two phases are very briefly summarized, stressing intrindividual differences. In the third phase, which took place 8 years later, follow-up of the school records was obtained, and it was possible to distinguish several groups of students on the basis of their postcompulsory schooling. Several hypotheses are advanced, but they are only partially supported by the results for the potential relations between types of schooling on the one hand, and for the modes of processing inferred from the intrindividual patterns observed in the Piagetian tasks on the other.

In this article, we focus on individual differences in cognitive development, as assessed with Piagetian tasks. We report on a program of research on intra- and interindividual variability conducted in collaboration with Lautrey in Paris. Our main objective was to study the extent and the form of intra- and interindividuality variability while building a model to integrate developmental and differential aspects. This led us to question whether there are different developmental paths for different types of children.

First, we briefly review how individual differences have been dealt with by cognitive developmentalists. We suggest that only a multidimensional approach that considers several underlying processes can account for universal, developmental aspects and for individual differences. Although these processes coexist in all individuals, their relative weight may vary across subjects. This is what Reuchlin (1978) meant when he proposed the notion of vicarious processes. It is embodied here in the concept of different processing modes. Second, these theoretical propositions are empirically illustrated using the results of a longitudinal study. Finally, the relations between cognitive performance on the Piagetian tasks and schooling are analyzed.

ON THE NECESSITY OF INTEGRATING DEVELOPMENTAL CHANGE AND INDIVIDUAL DIFFERENCES

There are three ways in which individual differences have been dealt with in developmental psychology. They are closely linked to the factorial models that have been proposed in the domain of intelligence (Reuchlin, 1985). Among the latter models, there is a unidimensional perspective, such as Spearman’s, in which individual differences consist essentially in quantitative variations around a same norm (g factor). Transferring this model to development implies that individual differences, when they are considered, are merely differences of speed along the same developmental path. In the Piagetian model, as well as in more recent developmental models, the only possibility allowed is that children of the same age differ from each other in the speed with which they reach a certain level. For instance, children may master conservation concepts earlier than others, but the manner and the order in which these concepts are constructed are supposed to be identical for all children. In such a context, individual differences are not considered to contribute to the theoretical model; therefore, traditionally they have been ignored.

An alternative multidimensional view can be adopted, similar to that of Thurstone or Guilford, in which a large number of underlying independent factors are postulated. In developmental terms, this implies that individuals proceed along many equivalent, independent paths. Although nobody
really sustained the view that there is no general developmental factor, recent cognitive models suggesting that development is essentially domain specific (e.g., Gardner, 1983; Keil, 1981) could be considered to adopt this perspective. Furthermore, following original suggestions by Burt and Spencer, a few studies have shown an increasing differentiation with age (for a discussion, see Reuchlin, 1985; Reuchlin & Bacher, 1989).

The two positions just discussed can be viewed as two opposing poles, between which there is middle ground, just like the hierarchical models of intelligence, which have sought to reconcile the positions of Spearman and Thurstone. Development is considered to consist of both a general, developmental factor and of group factors. Therefore, development can still be viewed as embodying general aspects, as in the first alternative; however, individual variability is important enough to yield different paths for different individuals. The number of such paths nevertheless would be more limited than in the second alternative and would be constrained by the general developmental factor.

This third position is the one that we adopted, and it has been supported by empirical results, as we try to demonstrate. Indeed, our main postulate is that most intellectual performances are to be understood as multidetermined or overdetermined; that is, they are under the combined influence of several sources of variation, both general and specific. The general sources can be understood as a general developmental factor in terms of subjects, and as a general factor of complexity in terms of variables. The specific sources of variance consist of situational differences and of different processing modes in individuals; this is, of course, close to what is now referred to as situated learning (Brown, Collins, & Duguid, 1989; Resnick, 1989). We also argue that there is a constant interaction between the situational and the individual characteristics.

DEFINITION OF TWO VICARIOUS MODES OF PROCESSING

Hypotheses about different processes at play in the Piagetian tasks used in our project relied on two types of distinctions: namely, the differentiation made by Piaget between logico-mathematical (LM) and infralogical (IL) operations on the one hand, and the differentiation introduced in cognitive psychology between propositional and analogical representations on the other hand.

The distinction between LM and IL operations refers to a difference in scale, and not to a difference in level of elaboration (Piaget & Inhelder, 1947). LM operations deal with relations of resemblance or difference between discrete (discontinuous) objects; IL operations structure continuous properties and relations of proximity between parts of the same object. Therefore, the term IL does not imply a lesser degree of elaboration, but instead indicates that the object itself and its parts are dealt with, in contrast to a set of discrete objects in the case of LM operations. Furthermore, these two types of operations are considered isomorphic by Piaget (Piaget & Inhelder, 1947), from the standpoint of their formalization. This distinction proved relevant in classifying the different tasks used in our project, and in understanding patterns of between-task relations.

The differentiation between a propositional and an analogical format of representation, which is now commonly accepted after a rather long period of controversy (Denis, 1989; Kosslyn, 1989; Mandler, 1983; Paivio, 1986), proved fruitful in understanding the processes at work in the two types of tasks. In a propositional format or mode of representation, relations between objects and representations are arbitrary. The different units are usually assembled through rules that are extrinsic to the representation (e.g., logical rules). The nature of a propositional mode is analytical or separable (e.g., Klemmer Nelson & Smith, 1989; Mandler, 1983), and processing is likely to be sequential. This mode is therefore particularly adapted to solving LM tasks. In contrast, the analogical mode is more global or holistic (integral) and embodies, in a single representation, units of information and their spatio-temporal relations. It maintains a certain isomorphism between the external events and their representation, which makes it a likely candidate for solving IL tasks. The use of one mode or the other is therefore assumed to be linked to situations. A propositional mode is probably more adequate to deal with LM tasks, whereas an analogical mode is probably more adapted to IL tasks. Note, however, that there is not a one-to-one correspondence between modes of processing and tasks. Either mode can probably be applied to either type of task. Still, we argue that using an analogical mode of processing for IL tasks is probably less costly in terms of resources, whereas using a propositional mode of processing in LM tasks probably leads to solutions considered to be more logical (e.g., Bideaud & Houdé, 1989). Note also that the Piagetian model emphasizes the logical aspect of both LM and IL operations.

Furthermore, individuals probably differ with respect to the availability of either mode. Reuchlin (1978) suggested the concept of vicarious processes to articulate situational and individual differences. Such processes obey a number of principles:

1. Several adaptive, often redundant processes coexist in each individual. They are construed as equivalent in complexity. Couched in the terms of an analogical and a propositional mode, this means that these two modes are present in all individuals.
2. Processes may differ in evocability or accessibility.
3. Evocability of processes may differ for different individuals (i.e., interindividual variability). In this case, this means that some subjects may prefer to rely first on a propositional mode (even though they may change mode in a later phase of processing), whereas other subjects prefer to use an analogical mode first.
4. Evocability of a given process may also differ according to situations (i.e., the source of intraindividual variability).
5. For a given situation, different processes may prove more or less efficient, even though they may be equivalent in their evocability. As already mentioned, a propositional mode is probably more adapted to LM tasks, whereas an analogical mode may prove more efficient for IL tasks.

6. The different processes may also interact, being complementary in certain cases and leading to cognitive conflicts in other cases.

It follows from these principles that certain subjects may prefer to rely on a given mode, even though it may not be the most adequate for a given situation. Optimal functioning appears to depend on an interaction between type of situation and mode of processing, and therefore on a flexible usage of each mode. The potential interactions between modes of processing and situations may account for the different types of decalages observed in our study: a higher level in the LM tasks when there is a preference for a propositional mode, and a higher level in the IL tasks when there is a preference for the analogical mode (for details, see Lautrey et al., 1990; de Ribaupire, 1993; de Ribaupire, Rieben, & Lautrey, 1991; Rieben, de Ribaupire, & Lautrey, 1990).

Although the two modes are construed as developmentally equivalent, they may well induce different scholastic achievements because formal schooling consistently grants a more important role to analytical or propositional processes, at least for older students and in a majority of disciplines. Consequently, children presenting a marked preference for an analogical mode may be at a disadvantage (e.g., Glober-son, 1985, 1989).

EMPIRICAL ILLUSTRATION

We report here on a three-phase project. A number of years ago, we launched a research project on intra- and interindividual variability using Piagetian tasks. Its objective was to assess not only the magnitude of such variability, but also its form. This study was first meant to be just cross-sectional, but it was extended so that all children were examined a second time.

In the first phase, 6- to 12-year-olds were given eight Piagetian tasks, adapted to cover the whole age range and to span different domains. In the second phase, the six younger age groups (i.e., the 6- to 11-year-olds), then 9 to 14 years old, were seen again 3 years later and given the same tasks. In the third phase, which was recently completed, the data base was reactivated and school records of the longitudinal subjects, now 17 to 23 years old, were obtained. Because results of the first two phases have already been published in several places (e.g., Lautrey et al., 1985, 1986, 1987; de Ribaupire, et al., 1991; Rieben et al., 1983, 1986, 1990), they are summarized here only very briefly, with a focus on the multivariate analyses; the third phase is reported in more detail. Table 1 summarizes the experimental design.

PHASE 1: THE FIRST ASSESSMENT

As mentioned, eight Piagetian tasks were administered to 154 children aged 6 to 12 years old (22 per age group). There were two LM (Intersection of Classes and Quantification of Probabilities) and six IL tasks. Of the IL tasks, two addressed the domain of physics (Conservations, Islands), two were spatial (Unfolding of Volumes, Sectionings of Volumes) and two were mental-imagery tasks (Line Folding, Folds and Holes).

Several analyses were conducted on the data, either on pass-fail items or on scores based on a qualitative system of analysis, which was elaborated to define structural correspondences between intermediate behavior levels across tasks. All analyses were convergent and pointed to a very large interindividual variability; for instance, some 7-year-olds were observed to be at higher levels than 11- or 12-year-olds. This led us to conclude that it is rather risky to use Piagetian tasks to assess a given child's cognitive level (de Ribaupire & Rieben, 1987). Intraindividual variability was also very high, as attested by numerous large decalages between tasks.

We focus here on the multivariate analyses that were conducted on both occasions on pass-fail items. There were constraints on the type of method that could be used, and this

### TABLE 1

<table>
<thead>
<tr>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
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<tbody>
<tr>
<td><strong>Data collected</strong></td>
<td><strong>Data collected</strong></td>
<td><strong>Data collected</strong></td>
</tr>
<tr>
<td>8 Piagetian tasks (38 items):</td>
<td>8 Piagetian tasks (38 items):</td>
<td>School records</td>
</tr>
<tr>
<td>2 LM tasks</td>
<td>2 LM tasks</td>
<td></td>
</tr>
<tr>
<td>Intersections of Classes</td>
<td>Intersections of Classes</td>
<td></td>
</tr>
<tr>
<td>Quantification of Probabilities</td>
<td>Quantification of Probabilities</td>
<td></td>
</tr>
<tr>
<td>6 IL tasks</td>
<td>6 IL tasks</td>
<td></td>
</tr>
<tr>
<td>Conservations</td>
<td>Conservations</td>
<td></td>
</tr>
<tr>
<td>Islands</td>
<td>Islands</td>
<td></td>
</tr>
<tr>
<td>Sectionings of Volumes</td>
<td>Sectionings of Volumes</td>
<td></td>
</tr>
<tr>
<td>Unfolding of Volumes</td>
<td>Unfolding of Volumes</td>
<td></td>
</tr>
<tr>
<td>Line Foldings</td>
<td>Line Foldings</td>
<td></td>
</tr>
<tr>
<td>Folds and Holes</td>
<td>Folds and Holes</td>
<td></td>
</tr>
</tbody>
</table>

*Note. LM = logico-mathematical; IL = infrastructural.

*8 = 154. *Age range = 6-12. *N = 117. *Age range = 9-14. *N = 105. *Age range = 17-23. For the two older age groups, fewer tasks were administered (15 items retained for the present analyses).
is why we turned to correspondence analysis (Benzeci, 1973; Lautre & Gibois, 1991; Lautrey et al., 1986, 1987). Most factor-analytic methods use correlations computed on variables assumed to be continuous and to have normal distributions. Clearly, these properties cannot be assumed in Piagetian tasks. Correspondence analysis has the advantage of being at the level of nominal variables, because it is a decomposition of a chi-square. It is also interesting because it can uncover potential hierarchical relations (e.g., a general factor) along with potential equivalence relations (e.g., group factors). A third advantage of correspondence analysis is that it deals simultaneously with variables and subjects. Therefore, the developmental profile of those subjects contributing most to factors that account for relations between variables can be identified easily.

Correspondence analysis was thus applied to the data obtained on the first occasion for 38 items and 154 individuals. Analysis yielded three interpretable factors (Lautrey et al., 1986). We focus here only on the first two. The first factor (General), accounting for 30% of the variance, could be interpreted as a general factor of complexity (as regards items) and as a general factor of development (as regards subjects). The second factor (LM–IL) accounted for 14% of the variance and contrasted LM items with IL items. These results back up the theoretical position defended earlier, and attest that the LM–IL distinction is a relevant dimension for understanding between-task relations and individual differences.

To illustrate the interindividual variability in intrindividual variability, Table 2 presents the profiles of the 10 most extreme subjects (5 on each pole) and the 13 most extreme items, that is, of the subjects and the items that contributed most to the definition of the LM–IL factor (part of chi-square, for which the axis accounts). In Table 2, items and subjects are ordered as a function of their decreasing contribution to the factor. The percentage of passes is also presented and indicates the level of difficulty of each item. The patterns of these 10 subjects are prototypical of what we labeled as individual decalages (Lautrey et al., 1981, 1987; Longeot, 1978), that is, decalages in different directions for different subjects. Note that scores on this factor were linked to neither sex nor age. These are obviously the most extreme patterns, and subjects were situated along a continuum going from LM to IL.

These results, together with the other analyses we conducted, clearly demonstrate that subjects differ in terms of the processes they rely on in these tasks. Indeed, if some subjects can solve relatively difficult LM items while failing relatively easy IL items, and if other subjects present the opposite pattern, this means that these two types of subjects rely on different processes for treating the same information.

**PHASE 2: THE FOLLOW-UP STUDY**

As mentioned earlier, all age groups except the oldest one were examined a second time 3 years later with all or most tasks.1 We center here on the stability of individual differences from Time 1 to Time 2, and not on the magnitude of the developmental change per se; that is, we focus on whether subjects maintained their relative positions and not on how much they progressed.

Correspondence analysis proved useful again from a longitudinal point of view. It provided a means of plotting

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**TABLE 2**

Examples of Extreme Patterns of Passes on Selected Logico-mathematical (LM) and Infralogical (IL) Items

<table>
<thead>
<tr>
<th>Passes</th>
<th>LM Items</th>
<th>IL Items</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>(N)</td>
<td>100</td>
<td>76</td>
</tr>
<tr>
<td>%</td>
<td>65</td>
<td>49</td>
</tr>
<tr>
<td>Propositional subjects (sex/age)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M/7</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>M/9</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>M/9</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>F/12</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>M/10</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

| Analogical subjects | | | | | | | | | | | | | |
| F/11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| M/12 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| F/10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| M/12 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| F/6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |

**Note.** From "Les Différences Dans la Forme du Développement Cognitif Évalué Avec des Épreuves Piagétienes: Une Application de L'analyse des Correspondances" [Differences in the form of cognitive development assessed with Piagetian tasks: An application of correspondence analysis], by J. Lautrey, A. de Ribaupierre, and L. Rieben, 1986, Cahiers de Psychologie Cognitive, 6, p. 60. Copyright 1986 by Cahiers de Psychologie Cognitive, Marseille. Adapted by permission. 1 = pass score; 0 = fail score. Items and subjects are ordered as a function of their decreasing contribution to the factor in correspondence analysis.
individuals as supplementary elements in the multivariate space defined by one analysis. Indeed, conducting separate factor analyses on two sets of data may lead to factors having a different meaning, whereas plotting supplementary individuals provides a way to constrain the meaning of the factors emerging on both occasions. It is then possible to compare coordinate positions of individuals on the first occasion and their coordinates as supplementary individuals on the second occasion (for details, see Launay & Cibois, 1991); this shows the extent of change from the first occasion to the second.

Figure 1 shows the space of subjects for the two factors described earlier: General and LM-IL. This space was defined for the 6- to 12-year-olds at the first assessment. This particular figure reports only the subjects who were 6 to 9 years old on Time 1; each subject is plotted twice, once for Time 1 (when they contributed in part to the definition of the space) and once for Time 2 as supplementary individual.\(^2\) They can be identified in the following manner: The first digit stands for age on Time 1 (6 to 9 years), the next two digits stand for the subject’s code, and the last digit stands for the occasion (1 for Time 1 and 2 for Time 2). Four quadrants are defined: Quadrant A corresponds to subjects who are relatively low on the General factor and tend toward the IL pole on the LM-IL factor (low/analogue); Quadrant B contains subjects who are high on the General factor and tend toward the IL pole (high/analogue); Quadrant C defines subjects who are low on the General factor and tend toward the LM pole (low/propositional); and Quadrant D contains subjects who are high on the General factor and tend toward the LM pole (high/propositional).

We expected subjects to progress on the General factor from Time 1 to Time 2, but to remain fairly stable on the LM-IL factor; this means that they could move from Quadrant A to B or from Quadrant C to D. A few subjects are singled out from this complex figure. It can be seen, for instance, that Subject 6011 (6012 on Time 2) presents a large progression on the General factor, but remained analogue; Subjects 7021 (7022) and 7081 (7082) present the same trends, even though the progression of 7081 on the General factor was smaller. It should be remarked that, on the LM-IL factor, the relative positions of 6011 and 7021 changed from Time 1 to Time 2: Subject 6011 was more analogue than Subject 7021 at Time 1, whereas the reverse was true at Time 2. Similarly, Subjects 6171 (6172), 8061 (8062), and 9161 (9162) progressed on the General factor and remain propositional, although their relative position on the LM-IL factor is modified. In contrast, Subject 7111 (7112) can be considered analogue at Time 1 and propositional at Time 2.

We also computed correlations between the two occasions. Correlations are obviously much more sensitive to slight interindividual differences in intrapersonal change than the qualitative description just made. To control both for the age effects (regarding the General factor in particular) and for differences in items given to the younger and to the older subjects on both occasions, correlations reported here were based on ranks on the two factors, instead of the coordinates per se. That is, subjects were ordered within an age group on each factor, for both occasions.\(^3\) These between-occasion correlations were both highly significant (.66 and .23 for General and LM-IL, respectively, p < .01). This attests to a rather high stability in individual differences, considering that all variance due to age was removed. The relative stability obtained on the LM-IL factor (even though lower than the correlation for General) tends to support our hypothesis that there are different developmental paths for different subjects.

**PHASE 3: RELATION BETWEEN THE FACTORIAL SCORES AND THE TYPE OF SCHOOLING FOLLOWED**

As previously discussed, we recently obtained from the school board the school records of the longitudinal subjects, who were then 17 to 23 years old. It was possible to get information for 105 subjects, concerning the curriculum followed for 3 to 5 years after the end of compulsory school.

Given the hypothesis that school may favor a propositional type of thinking, we were interested in knowing whether there was a relation between individual differences on our tasks defined in terms of processing mode and the type of curriculum followed after compulsory school.

A brief explanation of the Genevan school system is first necessary. All students go to junior high school until 15 years of age, which corresponds to the end of compulsory school. Then, for further training, they can go into senior high school, which is university bound, or to various technical or professional schools, which may require 4 to 5 years of study, but do not provide automatic entrance to the university. They can also enter an apprenticeship; that is, undergo professional training in the work place.

Given their age, the older subjects of the longitudinal sample should all have completed secondary school (even in the longest streams) or finished their apprenticeship. A few subjects among the youngest age groups could, however, still be found in the postcompulsory secondary schools.

\(^{1}\)Actually, fewer tasks were given to the 13- and 14-year-olds, due to time constraints and ceiling effects. However, we do not go into detail about this in this article.

\(^{2}\)Only the younger subjects are plotted here, because the 13- to 14-year-olds on Time 2 did not receive all items. They did contribute to the definition of the space defined in Figure 1, and could have been reported for Time 1 only. However, for reasons of figure readability, they were not retained.

\(^{3}\)The ranks were established on the coordinates provided by the correspondence analyses; however, two different correspondence analyses were performed. With respect to the 6- to 9-year-olds (9 to 12 at Time 2), coordinates on the factors defined on the 38 items and shown in Figure 1 were used. With respect to the 10- to 11-year-olds (13 to 14 at Time 2), the coordinates were issued from an analysis based on the 15 more difficult items only. The same method as described earlier was used: A correspondence analysis was performed on these 15 items on Time 1 for 9- to 12-year-olds, and the 13- to 14-year-olds on Time 2 were projected into this space as supplementary individuals.
FIGURE 1  Space of subjects on Time 1 and Time 2. Subjects are plotted twice: 6- to 9-year-olds on Time 1 and 9- to 12-year-olds on Time 2 (as supplementary individuals). They can be identified in the following manner: The first digit stands for age on Time 1 (6 to 9 years), the next two digits stand for the subject’s code, and the last digit stands for the occasion (1 for Time 1 and 2 for Time 2).
As mentioned earlier, we obtained data until the end of schooling for 105 subjects, all of whom had been examined twice with the Piagetian tasks. School trajectories were quite diverse. We finally chose to group them into five classes (see Table 3). Group 1 (G1) is composed of students who all had obtained or were about to obtain the baccalaureate, which means that they could enter university. Unfortunately, given the data we could gather, we could not introduce any finer distinction among the university-bound students. Group 2 (G2) is composed of students who followed secondary schools of a general or commercial type; they cannot usually enter university. Group 3 (G3) is composed of students who followed technical (engineering) or art schools. Group 4 (G4) corresponds to an apprenticeship of a clerical type. Group 5 (G5) corresponds to an apprenticeship of a manual type. The number of subjects in each group is very different, and varies according to sex and socioeconomic status (SES), which is not surprising.

It was hypothesized that the General factor should account, in part at least, for the type of school followed, whether of an academic type or not. With respect to the LM–IL factor, the hypothesis advanced earlier—that analogical subjects may be at a disadvantage given the requirements of the school system—led to the following predictions. Students in a university-bound stream (G1) should tend to be located toward the LM pole, whereas students in a professionally bound stream (G2 to G5) should tend to be closer to the IL pole. Furthermore, within the professionally bound group of students, we hypothesized that propositional subjects would prefer to attend clerical or commercial types of schools, whereas analogical subjects would be found in technical or manual types of schooling.

It should be stressed that no relation of causality is postulated. It is obviously not possible, on the basis of the present study, to know whether schooling strengthens individual differences in processing modes, or whether individual differences in processing modes influence the type of schooling followed. It can only be mentioned that individual differences in processing modes are rather precocious, because they were observed in children as young as 6 or 7 years old (i.e., that is, before they could be very much influenced by schooling).

To summarize the data on the Piagetian tasks for the two assessments, we computed a mean rank on the two occasions for each factor. Results (i.e., mean ranks for each factor and each group) are indicated in Figure 2. Note that a high rank score means being low on the General factor and being analogical for LM–IL. Thus, with respect to the General factor, G1 should have had a lower rank than the other groups, in particular lower than G4 and G5. It can be seen in Figure 2 that G4 and G5 tend indeed to have higher ranks than G1 and G3; however, G3 has an even better score on the General factor than G1. With respect to the LM–IL factor, G1 should have had a lower rank than the four other groups; G2 and G4 should have had lower ranks than G3 and G5. This is not exactly what was obtained. If G1 seems to be slightly more propositional, the differences among the four other groups does not seem very large, nor are they even in the expected direction.

Two one-way analyses of variance (ANOVA) were performed on the mean ranks, one for each factor. For the General factor, results showed that the variation in types of schooling was significant, $F(4, 100) = 5.29, p < .01$. Tukey tests showed that G1 is significantly lower ($p < .01$) than G4 and marginally lower ($p = .07$) than G5; the hypothesis that G1 would obtain better ranks on the General factor was thus only partially supported because it differs neither from G2 nor G3. Furthermore, G3 is significantly lower ($p < .01$) than both G4 and G5, which was not expected. This may be because G3 is both heterogeneous and small. It comprises students who chose engineering and art schools; even pooled together, these two subgroups amount to only 12 students. None of the other between-group differences was significant.

For the LM–IL factor, the one-way ANOVA showed a slightly less significant effect of schooling, $F(4, 100) = 2.61, p < .05$. Tukey tests showed that the only significant difference ($p < .01$) was between G1 and G4, G1 being more propositional than G4. This difference fits our hypothesis. However, the expected differences between G1 and the other three groups, and between G3 and G5 versus G2 and G4, were not confirmed.

### TABLE 3

<table>
<thead>
<tr>
<th>Group</th>
<th>Sex</th>
<th>SES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td></td>
</tr>
<tr>
<td>University bound</td>
<td></td>
<td>105</td>
</tr>
<tr>
<td>G1: Senior high</td>
<td>16</td>
<td>51</td>
</tr>
<tr>
<td>(baccalaureate)</td>
<td>26</td>
<td>54</td>
</tr>
<tr>
<td>Professional</td>
<td></td>
<td>105</td>
</tr>
<tr>
<td>schools</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G2: Commercial</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>11</td>
</tr>
<tr>
<td>G3: Technical</td>
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<td>11</td>
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<tr>
<td>Apprenticeship</td>
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<td>G4: Clerical</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>11</td>
</tr>
<tr>
<td>G5: Manual</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td>54</td>
<td>46</td>
</tr>
</tbody>
</table>

### DISCUSSION

The objective of this article was twofold: first, to stress the contribution that a differential approach can make to general developmental theories; and second, to focus on the possible relations between individual differences in processing modes (as shown in Piagetian tasks) and schooling. This second objective was meant to be mainly exploratory.

We mentioned that most developmental models are unidimensional in nature, whereas we argued that a multidimensional perspective should be adopted, which would allow for...
the existence of different developmental paths for different types of children. The empirical study that was briefly reported here indeed demonstrated that, along the General factor, group factors can emerge from factor analyses. This finding confirms that the tasks are not homogeneous and tend to group in different clusters, which are compatible with the factor-analytic hierarchical model of intelligence of the Burt-Vernon type obtained with psychometric tasks and suggesting a distinction between a verbal and a spatial factor. With respect to Piagetian tasks, other researchers have obtained results similar to ours, that is, a general factor and at least two group factors corresponding to LM tasks on the one hand and IL tasks on the other hand (e.g., Humphreys & Parsons, 1979; Humphreys, Rich, & Davey, 1985; Inman & Secrest, 1981; Longeot, 1978; for a review, see Lautrey et al., 1990). The latter distinction seems close to the psychometric verbal–spatial differentiation; however, a strict one-to-one correspondence is unlikely, so much more so because Piagetian tasks do not directly address verbal aspects.

The interest of correspondence analysis, used in this article, is to afford simultaneous representation of variables and individuals on the same axis system; this facilitates the comparison of the two structures found in each of these two spaces. The LM–IL factor in terms of tasks can be interpreted as corresponding to two different processing modes used by subjects. These modes, labeled propositional and analogical, are to be considered as vicarious processes, in the sense suggested by Reuchlin (1978).

Furthermore, correspondence analysis allows supplementary elements to be located in a space to the definition of which they did not originally contribute. This is very important in a longitudinal study, and it allows the meaning of the factors to be controlled across time. Correlations of rank scores between Time 1 and Time 2, controlling for age, were significant for each factor. Even though lower than for the General factor, the correlation for the LM–IL factor attests to a relative stability, which in turn supports the hypothesis that there are different developmental paths for different types of children.

When considered within an educational framework, a possible outcome of this type of study would be to question whether such cognitive characterization of subjects relates to school achievement. The link between the General factor and school achievement has been well documented (e.g., Reuchlin, 1991; Snow & Lohman, 1984). The relation that the LM–IL factor may entertain with scholastic achievement is less well known. One can assume, like Globerson (1985) for instance, that analogical subjects are lower performers in general, considering the requirements of most school systems. In addition, it may be the case that there is an interaction between types of individuals and school subjects; for instance, individuals favoring a propositional mode may prefer and be more successful in LM school domains, whereas individuals preferring an analogical processing mode might be more at ease in subjects involving spatial representation, possibly also in art domains.

In this study, scholastic achievement was assessed in a very indirect and coarse manner, because individuals were only distinguished according to the type of schooling attended after compulsory school. Individual variability in cognitive functioning is certainly not the only factor, nor probably the most important one, in the choice of postcompulsory training. Many other variables may contribute to this choice, such as previous school achievement or motivational, social and family factors. Nevertheless, there was a link between results on the Piagetian tasks and schooling, in particular with the General factor. As expected, university-bound students (G1) tended to rank better on the General factor and be more propositional, even though all differences were not significant. G3 (i.e., the group attending technical or art schools) did
not behave as predicted; it ranked best on the General factor and turned out to be more propositional than expected. There was no difference among the three other groups. The most surprising result is that of G3. As mentioned, this may simply be because this group is relatively small and heterogeneous. Its greater-than-expected similarity with Group 1 could also originate in the fact that these two groups of students engage in longer types of schooling. Furthermore, it could be the case that technical and art schooling paradoxically requires LM ability as much as it requires spatial ability, if not more so. It should again be stressed that a propositional mode of processing is not to be equated with verbal aptitude; therefore, the commonly held (but not necessarily correct) hypothesis that a technical type of schooling may place less emphasis on verbal than on visuospatial aspects may not contradict the supposition that this type of schooling also reinforces a propositional mode of processing. Nevertheless, we expected that it would enhance an analogical mode of processing.

In conclusion, the lack of clarity of the relations between school orientation and results on Piagetian tasks is not very surprising, given the profusion of variables that can contribute to the choice of a career. It may also be the case that the Piagetian tasks underestimate verbal ability and that a verbal factor, rather than the LM–IL factor defined here, is a better predictor of school achievement. In any case, these results need replication. In particular, more contrasting subjects should be examined and more balanced groups should be constituted.

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