A Probabilistic Modeling of the Writing Strategies Evolution for Pupils in Primary Education


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Abstract. The goal of this paper is to bring a contribution to the realization of the evolution follow-up in writing among typical pupils in primary education. We propose a method for the temporal modeling of these pupils writing strategies. We developed a software for the on-line acquisition of writings and the automatic extraction of features from handwritings. Distributed on three periods of about six months each, these acquisitions have therefore been achieved three times for the same pupils in the same experimental conditions. An unsupervised classification (clustering) is applied to highlight strong (i.e. steady) clusters on a set of dynamic primitives chosen by an expert in the field of child's development psychology. Results are presented by means of a comparative study between features of each group and writing tests. From a cognitive point of view, the behavior of a group could be the fruit of a specific central representation self actualizing by common expertise of the pupils at the motor program level. We finally illustrate graphically the temporal flux within and between-strategies, and this concretizes the probabilistic modeling of the rates of pupils that change (respectively don't change) their writing strategies during an interval of one year time.

1. Introduction
Writing is the object of a specific training since the nursery school. From the point of view of the motor actions developed in the writing, the child is going to be able to transpose to the tracing of letters the experience acquired in the drawing production. During the progression of his training, quantitative differences (speed, precision...) as well as qualitative ones (legibility) are going to appear [1, 2, 3]. These differences are due to the training in class, to the spontaneous exercise, but also to the maturation of the motor system and to the changes occurring at the biomechanics level [4]. These results reinforce the idea that "there are some features of the writing that can be used like indicators of the development level". Thus, from Meulenbroek, Van Galen and Zesiger works [5, 6, 7, 8], Zesiger [9] suggests "the existence of a change in the strategy of programming of the writing movements". This paper studies the following questions: How can one clarify the notion of strategy as regards to the measured variables? Can one predict the temporal evolution of the writing strategies for a child? We assume that if features of writing of a set of pupils are close according to a given metric, then these pupils nearly share the same strategy of writing. With an automatic classification method, we highlight groups of typical pupils that share a same writing strategy, then we label them concretely through the spatio-temporal and kinematics features extracted from their tracings. In the following we define the tests, the extracted features and the pupils population that constitutes our database; then we present the approach that we use for the strategies discovery and the analysis of the temporal evolution of the groups in question. Finally, we illustrate the obtained results.

2. Tools and experimental protocol
Completing the works of Rémi and Amara [10, 11, 12], we developed a software allowing the on-line acquisition of handwritten tracings (drawings and writing) and the automatic extraction of primitives from these tracings. The experimental protocol consists of six tests: two drawings from the Bender Gestalt test (tests noted B_1 and B_2), writing of the first and last names of the pupil (Name), writing of an isolated word (Ta), writing of a sentence by copying it (Ph) and after memorizing it (Phm). Distributed on three nearly uniform periods of six months (T1, T2 and T3), the acquisitions have been achieved three times for the same pupils in the same applied conditions. 102 pupils participated thus to our experiments; they are distributed on the five first primary classes (i.e. CP, CE1, CE2, CM1, CM2) (cf. Figure 1 for the strengths by class). The selected pupils redoubled no class, don't have established trouble of the oral or written language and have an age compliant to their school level.

1 A strategy is defined as a control mode (Zesiger, 1995); we consider thereafter that a set of near pupils in the sense of writing features shares the same strategy.
2 It is about the non supervised classification; indeed: the strategy is an abstract cognitive notion, we try to clarify it with features extracted from the writing.
3. Clustering

The data acquisition was done using a digitizer activated in temporal mode. For each one of our experimental tests, seven features were extracted: the average speed, the speed standard deviation, the number of strokes, the duration of pauses, the average acceleration, the fluency of the movement and the execution time. Whatever were the school levels, we have considered that: "series of data corresponding to a same pupil at two different acquisition periods constitute two different series of data". From this fact, we have represented our database with 306 pupils (i.e. 102*3), a pupil being characterized by a vector of 42 components (i.e. 7 features * 6 tests). The automatic classification has consisted in reducing the number of subjects by grouping them together in homogeneous classes. We have then focused our study on the obtained classes by considering that each one groups together the pupils who shared the same strategy of writing, and then we tried to label these strategies. We used the k-means method [16] that makes part of the adaptive automatic classification methods. The initial cores were randomly chosen; the comparison of the elements to group together was done using the euclidean distance; the criterion of stability consisted in iterating the k-means algorithm several times; the classes that resisted to the risks due to the random choice of the different families of cores were considered as strong forms [13]. From the method described above, we have obtained six groups (A, B, C, D, E, F). The proportion of the number of pupils in each group is given in figure 2.

4. Results

We illustrate the obtained results by a comparative study between the graphs of figure 3, each graph representing the behavior of a feature average value on each of the tests and according to the obtained clusters. Whatever are the tests of our protocol, we notice that the pupils of groups C and E write faster than the pupils of groups D and A, and that the speed of these later is higher than the one of the pupils of groups B and F. We also notice that the fluidest groups are E, C, D, A, B, F (by descending order). We note that it is nearly the same order for the duration of execution (exception made for groups E and C), except in the two writing tests Ph and Phm. We then notice that groups F and B are the slowest and the least fluid and that their accelerations are the weakest; in the same way their duration of execution and pauses are a bit longer than those of the other groups. We also notice that they represent 11% (F=1.63%; B=9.4%) of our samples. Groups C and E get the highest scores in speed, fluidity and the lowest scores in duration of execution and pauses whatever are the features and the tests of our protocol, while A and D regroup the pupils with "mean" scores relatively to the other groups.

5. Temporal flux

The psychologists interested in the normal and/or pathological development try to establish the way the child's capacities alter with age or with the level of acquisition of a given expertise. They mainly try to describe successive strategies used by the child in the temporal mastery of an expertise [9]. In this context we present in figure 4 the results of our analysis made on the temporal evolution of the quoted groups (i.e. A, B, C, D, E, F). It enables to model the rates (or the probabilities) of change (resp. of stabilization) of within and between writing strategies during an interval of one year time. In figure 4, we illustrate the strategy evolution of our 102 pupils over time; columns and rows respectively correspond to acquisition time (T1, T2 and T3) and global strategies arrows (A, B, C, D, E, F) stand for pupil transition from one strategy to another over time. We here limit the presentation to the analysis of the temporal evolution of group A.

**Group A**

**Evolution T1 → T2:**

Let us recall that this group gathers the pupils who write with a quite averaged speed. We note that most pupils (i.e. 21/24 ≈ 87%) of this group have migrated between the first two periods of acquisition towards the groups of fastest and fluidest pupils (i.e. groups C, D and E), the rate of change being merely the probability that a pupil adopts a strategy S at T1 knowing that he adopted a strategy S' at T1. Being inspired by the works of Ziviani [3], one could interpret this change as being the result of a maturation of the program and the system motor among the pupils, due to the new expertise acquisition during vacations (vacations of summer between T1 and T2). We therefore consider that until 87%, this group gathers the pupils who show a "typical" evolution compliant to the model of writing acquisition as much as on the dynamic plan than on the motor one between the six months of the first two periods of acquisition.

**Evolution T2 → T3:**

We first notice that pupils at the time T2 that presented a typical evolution stay in the fluidest and fastest groups at the time T3, except for two of these pupils (i.e. 2/21) who integrate group F that is the least fluid. We also note that only one pupil (i.e. 1/24) adopts the same strategy one year later (time that goes by between T1 and T3). We consider that

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3 We accept this consideration after a discussion with psychological experts.
this strategy corresponds to the pupils who evolve (i.e. that change of motor behavior) between the three periods of acquisition.

6. Conclusion and perspectives
The goal of our paper was to bring an objective contribution to the follow-up of the pupils in primary education, problem to which the psychologists and the school pedagogues are confronted. Our contribution highlights "typical" pupil groups having in common the same strategies of writing. From an automatic classification method we clarified the behaviors of the writing of the pupils by the behaviors of the groups that generate them. Each group constitutes a coherent overall, better identifiable and more informative at the level of writing features. The prediction of the temporal evolution of these groups is quantified under a probabilistic form by specifying the rates of between and within-strategies change. According to the behavior of each group, this evolution will then be able to be qualified. From a cognitive point of view, the behavior of a cluster could be the fruit of a specific central representation; therefore the pupils grouped in a same cluster could share common expertise at the level of the motor program. From that point of view, the reasoning by groups seems to be interesting for the research of common structural properties in the movements of writing, theme of the Graphic Motricity theory landed by Hollerbach and Van Galen [14, 15]. It would be interesting to put features of the writing production in relation with the underlying cognitive processes. The obtained clusters should be individually analyzed following the situation of every pupil of a cluster.
Figure 4: Strategy evolution of our 102 pupils over time
Columns and rows respectively correspond to acquisition time (T1, T2 and T3) and global strategies (A, B, C, D, E, F)

References