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A FOLLOW-UP STUDY ON WRITING POSTURE AND WRITING MOVEMENT OF YOUNG CHILDREN

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SUMMARY 55 children who were subjects in an earlier study on writing behaviour (Blöte, Zielstra and Zoetewey, 1986), were tested 3 more times within one year after the first measurement. In this follow-up study the changes in overt motor variables of the writing behaviour of the children over time were investigated. It was found that the interrelationships within the set of variables are about the same at the 4 time points. That is, the structure of the variables remains more or less stable in time. What changes is the frequency of occurrence of several aspects of the writing behaviour. A growing number of children show high muscle tension in writing, and a low, forward leaning posture. Besides, there is an increase of more mature positions of the arm and hand, and of adequate grip postures. Some changes in the writing behaviour of the children are assumed to be related to the start of writing instruction in the first grade. Task effects that had been found at T1, also turn up in a sum analysis of all data.

Key words: Hand writing, posture, movement, young children

INTRODUCTION

In research on the motor aspects of handwriting little attention has been paid to variables that concern body posture and arm/hand movement (see a.o. Askov, Otto and Askov, 1970; Peck, Askov and Fairchild, 1980; Thomassen and Teulings, 1983). Knowledge of the development of these overt process variables of writing is important in everyday school practice. In teaching handwriting skill as well as in remediation of writing difficulties a close observation of the way in which the handwriting is produced seems obligatory. A teacher should know whether, considering the age of the child, a given pencil grip or arm movement or other posture or movement is deviant, and if so in which way. What is

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needed therefore, is a description of the normal development of pencil and paper manipulation and of the variables relevant for each age group. An earlier study on the writing posture and movement of Dutch children in kindergarten (Blöte, Zielstra and Zoetewey, 1986) showed that there was much variation in this group of children who were about to enter primary school. Body posture and pencil grip were the 2 most discriminating dimensions. In relation to these 2 dimensions the different aspects of writing behaviour were found to constitute 4 clusters. (1) "Forward leaning", a posture characterized by forward leaning of the trunk, low position of the head with the body covering the paper, in combination with high muscle tension. (2) "Upright", this posture being the opposite of the former one. There is a certain distance between the child and the paper, both in terms of body posture and of the height of the grip; and there is less muscle tension. (3) "Open arm position", in which the forearm is perpendicular to the line of writing and the hand is below the line. (4) "Forearm parallel", which goes with inadequate transport movements of the arm and a turned position of the body. As far as the different grips are concerned no relationship between the occurrence of an adequate grip (the tripod posture) and body posture has been found, but of the non-tripod grips some seem connected with "Forward leaning" and others with the "Open arm position".

In this paper we report on a follow-up study of one year on the same group of children. They were tested for a second time when they were still in kindergarten and a third and fourth time when most of them were in the first grade of primary school. The main purpose of this paper is to find out which changes appear in the writing behaviour of the children in the course of time. This has been studied in 2 different ways. (1) By focusing on the *structure* of the data; in other words the question is asked whether the dimensions and clusters that were found at T1 are also valid at T2 to T4, or, whether the writing behaviour of the children at the subsequent points in time can be better described by different sets of dimensions and clusters. And (2) by focusing on *shifting frequencies* of occurrence of the different aspects of writing behaviour. In this approach changes in writing behaviour over time will be described in relation to one given structure that is assumed to be valid for all 4 time points. Apart from that and starting from a different point of view we have studied a solution that maximizes the time differences in the data as far as shifts in frequencies are concerned.

Finally, we have investigated task effects on the writing behaviour of the children. In the first study it was found that the kind of pattern that was copied had its effect on arm and hand movement, and that the place on the paper where the copy was made influenced body posture and the position of the writing arm. We will examine whether these effects also appear in the follow-up study.

METHOD

Subjects

Of the 55 children in the first study some dropped out in the follow-up,* due to illnesses, technical problems with the video-recorder and an uncooperative school. The respective number of children taking part in the study was 55, 53, 46 and 54. During the third and the fourth measurement 7 children were (for an extra year) in kindergarten. The others were in the first grade of primary school.

Task

The tasks were the same as the ones used in the first study and they were given in the same order. In the third and the fourth measurement the children who by then were in the first grade, were also asked to copy 4 words. The words were written on the upper half of a separate sheet of paper (size A5).

Procedure

The video-taping of the writing children took place in June and October 1984 and in March 1985 (T2, T3, T4 respectively; T1 was in March 1984). In October the children had gone to school for nearly 2 months in the new school year.

The procedure was always the same except for T4 when only one experimenter—instead of 2—was in the room with the child. Because the experimenter had to tend the camera, the children were asked to go and get the sheets of paper (one by one), that were laid out for them at some distance from their table. As the children were used to the task by then, it was no problem that only one experimenter took care of both the child and the apparatus.

Observation

Observations were made from video-tape. The same observation list was used throughout the study, except that one category was added for the observations of T3 and T4, i.e., item 4, category 12 "Shoulders cannot be observed". The items on the list concern: (a) starting posture; (b) posture in the course of the line; (c) grip postures; (d) transport movement.

The observations of T2 were made by the same 2 observers who had done T1. For T3 and T4 a diff. nt observer was used who had been thoroughly trained by the former 2. This observer also had regular deliberations with a fourth observer who had experience with the observation list. Parts of the tapes were observed by both of them for

* A more detailed description of the subjects and the method is given in Blöte, Zielstra and Zoetewey (1986)

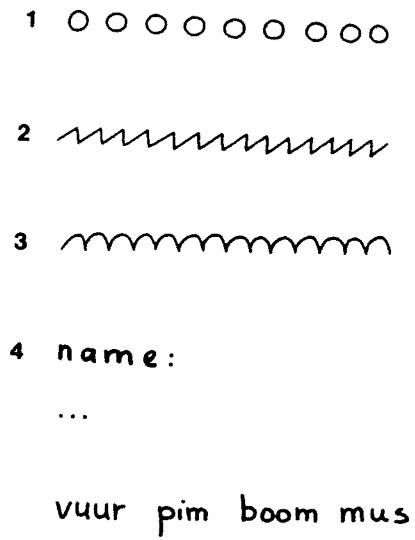

Figure 1. Patterns, name, and words.

reliability reasons, i.e., to check whether the observations were consistent in time. The rate of agreement between the first 2 observers and the third one was calculated for 25 cases. For only 2 items the agreement (number of cases of agreement/total number of cases scored) was less than 80%. Item 3 "Turning of the body" had an agreement of 76%, and item 12 "Head lowered close to the table" had an agreement of 72%. The calculated rate of agreement between the third and fourth observer over 51 cases was 77% for item 14 "Grip on the pencil" and more than 80% for all other items. The subjects were observed while copying 3 patterns (see Figure 1) and while writing their name (T1 and T2) or the 4 words (T3 and T4, for those who were in the first grade).*

Results

Changes in Structure

The analyses were made on cases instead of on subjects, each pattern written by a child being a case. Separate homogeneity analyses (Gifi, 1981; Tenenhaus and Young, 1985) were carried out for T2, T3 and T4

* In the following text the word "patterns" stands for patterns as well as name and words. Name and words were dealt with as if they were the same "pattern".

respectively (as had been done for T1; see Blöte *et al.*, 1986). For these analyses the items chosen were the same as for T1. We also opted for a two-dimensional solution. The results of T1 to T4 were compared both in terms of the first 2 dimensions and the clustering of item categories.

Considering the 6 items with the highest discrimination measures on the first dimension we found that item 10 "Body leaning against the table", item 9 "Shoulders bent forward to the table", and item 12 "Head lowered close to the table" have high values at each T.* Furthermore, item 1 "Forearm on the table" and item 13 "Angle arm axis-line of writing" make important contributions to the first dimension at 3 of the 4 time points. As far as the second dimension is concerned item 15 "Tripod posture" is the main contributor at all 4 T's. Item 18 "Pencil rests on second phalanx of middle finger" is also found to be contributing in 3 cases and item 17 "Thumb is not in opposition with index" in 2 cases. Regarding the clustering of item categories the following summary can be given. Clusters 1 and 2, "Forward leaning" and "Upright" (cf. Introduction), were found to be the main clusters at every T. Only minor shifts for 1 or 2 categories appear. Cluster 3 "Open arm position" gradually merges with cluster 2 "Upright", to which it was closest from the beginning. At T2 and T3 it can still be discerned, but at T4 it has become part of cluster 2. A reason for the disappearance of cluster 3 could be that category 21 "Hand lies below the line", having a low frequency at T1, becomes more common in the course of time. This category showed the largest distance from cluster 2 at T1. By becoming more common it lost the eccentric position in the plot (one of the properties of homogeneity analysis is that categories with a low frequency are often placed in the periphery of the solution; Gifi, 1981). Cluster 4 "Forearm parallel" disappears too. At T2 and T3 it still exists, although the distances between the categories grow larger. At T4 it becomes part of cluster 2. Seeing that the most eccentric category of cluster 4, i.e., category 38 "Angle arm-line of writing smaller than 30°", was no longer observed at T4, the disappearance of this cluster could be expected. As to the position of the grip postures no clustering was found at any of the time points. Category 45 "Index finger flexed" is always part of the "Forward leaning" cluster, and in 3 cases category 51 "Middle finger rests on pencil shaft" is also part of this cluster. Furthermore, categories 47 "Thumb is not in opposition with index" and 49 "Pencil on second phalanx of the middle finger" are always relatively close together. On the basis of the above mentioned results we conclude that the structure of the data at the different time points is essentially the same, although 2 clusters of rather infrequent behaviours gradually disappear with time.

Changes in Frequencies in Relation to a Common Structure

In order to relate shifts in the frequencies of categories over a given period of time to a given common structure, the first thing to do is to find such a structure. Instead of the 4 structures just presented *one* structure is needed that is valid at all 4 time points. For this purpose the data were analyzed in the following way. Usually in homogeneity analysis a matrix G is analyzed with n rows (here n is the number of children, equal to 55) and J columns (here J is the number of categories, equal to 68). Our matrix G has elements g_{ij}, with a value of either 1 or 0: $g_{ij} = 1$ in case child i displayed behaviour j, and $g_{ij} = 0$ if otherwise. In this way we constructed 16 different matrices G, namely one for each of the 4 tasks at each of the 4 time points. By simpy adding up these 16 matrices G an aggregate matrix $\bar{G}$ was obtained, in which values $\bar{g}_{ij}$ denote how many times child i displayed behaviour j: values $\bar{g}_{ij}$ range between 0 and 16. Matrix $\bar{G}$ was then submitted to homogeneity analysis and an average solution was obtained for the 55 children and the 68 categories. We will first comment on the dimensions that were found. The relative contributions of the items to each of the dimensions

Table 1 Starting positions

Items nr.	cat. nr.		Dimension 1	2	3
1	1	Forearm on the table	0·00	0·04	0·03
	2	in part on the table			
	3	not on the table			
2	4	Body leaning to the left	0·01	0·01	0·02
	5	upright			
3	6	Body turned to the right	0·02	0·03	0·00
	7	not turned			
	8	turned to the left			
4	9	Shoulders left one lift up	0·00	0·00	0·01
	10	horizontal			
	11	right one lift up			
	12	cannot be observed			
5		Distance paper-front edge of			
	13	the table < 0	0·00	0·02	0·00
	14	0 ⩽ d < 4			
	15	4 ⩽ d < 8			
	16	d ⩾ 8 cms.			
6	17	Wrist in extended position	0·01	0·02	0·05
	18	in line with forearm			
	19	in flexed position			
7	20	Hand lies on the line of writing	0·00	0·00	0·01
	21	below the line			

Table 2 Positions in the course of the writing line

Items nr.	cat. nr.		Dimension 1	2	3
8	22	Paper turned counterclockwise	0·02	0·01	0·01
	23	in perpendicular position			
	24	turned clockwise			
	25	not held in a fixed position			
9	26	Shoulders bent forward to the table	0·03	0·02	0·15
	27	in an upright position			
	28	intermittently bending forward			
10	29	Body leaning against the table	0·02	0·05	0·12
	30	not leaning			
	31	intermittently leaning			
11	32	Head turned to the right	0·03	0·00	0·01
	33	not turned			
12	34	Head lowered close to the table	0·06	0·01	0·14
	35	not lowered			
13	36	Angle arm axis-line of writing 60–90°	0·00	0·06	0·04
	37	30–60°			
	38	0–30°			

Table 3 Grip postures

Items nr.	cat. nr.		Dimension 1	2	3
14	39	Grip on pencil is very low	0·09	0·01	0·02
	40	low			
	41	middle/high			
	42	changes			
15	43	Tripod posture: yes	0·08	0·25	0·09
	44	no			
16	45	Proximal joint of index flexed 90° or more	0·17	0·00	0·00
	46	less than 90°			
17	47	Thumb is not in opposition with index	0·23	0·01	0·06
	48	is in opposition			
18	49	Pencil rests on the second phalanx of the middle finger	0·12	0·00	0·06
	50	on the third phalanx			
19	51	Tip of the middle finger rests on the pencil shaft	0·12	0·45	0·04
	52	does not rest on the shaft			

Table 4 Transport movement

Items nr.	cat. nr.			Dimension 1	2	3
20	53	Recurrent extension of the wrist:	yes	0·00	0·01	0·03
	54		no			
21	55	Displacement of hand while leaning on pencil or finger tips (crawling):	yes	0·00	0·00	0·02
	56		no			
22	57	Displacement with upwards canting of palm of the hand:	yes	0·00	0·00	0·01
	58		no			
	59	Recurrent lifting of the hand:	yes	0·00	0·00	0·01
	60		no			
24	61	Recurrent raising of the wrist:	yes	0·00	0·00	0·05
	62		no			
25	63	Recurrent lifting of the forearm:	yes	0·00	0·00	0·00
	64		no			
26	65	Rotation of the forearm around the axis of the upperarm:	yes	0·00	0·00	0·00
	66		no			
27	67	Whole arm movement:	yes	0·00	0·00	0·01
	68		no			

are given in Tables 1–4. In the following text we mention all values greater than 1/27 (= 0·037), thus paying attention to the items that contribute more than averagely.

On the first dimension the grip posture items "Thumb-index opposition" (17), "Flexion of the index" (16), "Middle finger on the pencil" (19), and to a lesser extent "Height of the grip" (14) and "Tripod posture" (15) have a relatively high value, whereas the posture item "Head lowered" (12) contributes only slightly. This dimension can therefore be interpreted as a grip posture dimension. The same is true for dimension 2, with the items "Tripod posture" (15) and "Middle finger on the pencil" (19), even though the arm/body posture items "Angle arm-line of writing" (13), "Body leaning" (10) and "Forearm on the table" (1) also contribute to this dimension, be it to a lesser extent. Comparing these dimensions with those of the 4 separate analyses, it is clear that grip postures have become more important in discriminating the subjects on the tasks. Here body posture appears on the second dimension, and even then only with limited importance in relation to the grip variables. This difference, between the separate analyses on the one hand and the combined analysis on the other, can be explained by the relative stability of the data. From the data on the changes within subjects over a period of time it shows that grip posture is a more stable aspect of writing behaviour than body posture. E.g., in the first three-month period 32% of the children changed categories with respect to item 12 "Head lowered to the table", while copying the circles. For item 15 "Tripod posture" this was 19%, and for item 19 "Middle finger on the pencil" it was only 9%. With respect to task effects grip posture also proved a more stable characteristic of writing behaviour than other items like body posture and transport movement (Blöte *et al.*, 1986). As we did not want to lose the body posture items for further analyses, we decided to examine the next higher dimensions in order to see if body posture would show up in one of them. The third dimension then turned out to be a body posture dimension (see Tables 1–4). Items 9 "Shoulders bent forward", 12 "Head lowered to the table", and 10 "Body leaning" have the highest contributions to this dimension. Less important are the grip items 15, 18 and 17, and the items 6, 24 and 13 concerning position and movement of wrist and arm. For a better insight into the clustering of categories, a plot was made of the first 2 dimensions (see Figure 2). All categories except those that are centered in or close to the origin were plotted. Concerning the grip postures we notice a first distinction

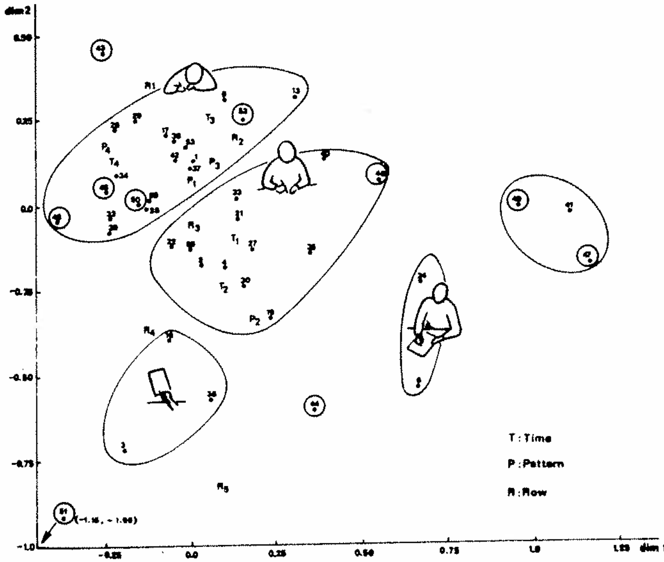

Figure 2. Clustering of item categories with respect to the first 2 dimensions, and average co-ordinates of the time points, the patterns, and the row numbers.

between tripod (cat. 43) and non-tripod (44) grips. In the plot 2 kinds of non-tripod grips can be discerned. The first one, in the middle right part of the plot, concerns a high grip on the pencil (41), a lack of thumb-index opposition (47), and an incorrect position of the middle finger (49), with the pencil resting on the second instead of on the third phalanx of this finger. The second kind of non-tripod grip "Middle finger on the pencil shaft" (51) lies in a very eccentric position in the lower left part of the plot. The dichotomy in the non-tripod grips is characterized by the role of the finger tips. In the former cluster the pencil is not held by the finger tips but by less distal parts of the fingers. In the latter grip the child uses the tips of the fingers—and 3 instead of 2 as in the tripod grip. In the upper left part of the plot we find the "Forward leaning" cluster. The body is leaning against the table (29), the head is lowered close to the table (34) and turned (32), the shoulders are constantly (26) or intermittently (28) bent forward to the table, and the body is turned to the left (8). The paper is placed close to the front edge of the table (13), while the whole forearm is resting on the table (1) and is either parallel to the line (38) or in an oblique position (37). In the starting position the wrist is extended (17). Moreover, the transport movement of the hand causes recurrent further extension (53). Recurrent lifting of the hand (59) also occurs. The grip on the pencil is very low (39) or it changes in height (42). The index finger is too flexed (45) in an otherwise correct grip posture (48, 50, 52). The "Upright" cluster, that is located in the opposite direction from the origin, concerns a posture in which the shoulders are not bent to the table (27) and the trunk does not lean to the table (30). Leaning to the left (4) however, can occur. The head is up (35), and not turned (33). The forearm rests only in part on the table (2), while the hand lies below the line of writing (21) and the wrist can be flexed (19). The paper is turned counterclockwise (22). There is no whole arm movement (68). The height of the grip is in the normal low range (40) and the index is not flexed too much (46).

Finally, there are still 2 smaller clusters. One of them, in the lower left part of the plot, concerns the position of forearm and paper. The papper is placed at a relatively great distance from the front edge of the table (16). The arm axis is perpendicular to the line of writing (36) and the greater part of the forearm sticks out off the table (3). This cluster is partly the same as the "Open arm position" cluster at T1. The other small cluster, located in the lower right part of the plot describes 2 very rare positions, in which the body is turned to the right (6), and the paper is turned clockwise (24). As to the third dimension we notice that a large part of the "Forward leaning" cluster is on the negative side of dimension 3 and part of the "Upright" cluster is on the positive side.* For the "Forward

* For lack of space we do not represent the plot of this dimension.

leaning" cluster the categories concerned are: "Shoulders bent to the table", "Body leaning to the table", "Head lowered to the table", "Angle arm-line of writing < 30°", "Hand in extension", and "Recurrent extension of the wrist". For the "Upright" cluster we find "Head not lowered", "Body not leaning", "Shoulders not bent", "Body leaning to the left", and "Flexion of the wrist". Furthermore, it should be noted that on the three-dimensional representation body posture and grip posture do not cluster together. However, from the two-dimensional projection of this cloud one can conclude that children leaning forward tend to show tripod postures, whereas children sitting upright tend to have different kinds of grips.

In order to relate the time variable to the structure mentioned above we have calculated the average time co-ordinates for each time point with respect to the 3 dimensions. By fitting these points into the solution we can see which clusters of categories are predominantly used during which points in time. As can be seen in Figure 2 T1 and T2 are located in the "Upright" cluster and T3 and T4 in the "Forward leaning" cluster. The same dichotomy has been found with respect to dimension 3. Therefore we can conclude that the changes of writing behaviour in time concern body posture more than grip posture. Furthermore, it becomes clear that the changes take place mainly between T2 and T3, i.e., when the majority of the children move up to grade 1. We shall elaborate on this in the discussion.

Finally, we calculated average points for the task effects with respect to the 3 dimensions, in the same way as we did for the time effect. By fitting the task effects into the solution we can study which clusters of categories are predominantly used for which tasks. Figure 2 shows that patterns 1, 3 and 4 lie in the "Forward leaning" cluster. On dimension 3 the patterns have comparable positions. As far as the row number effect is concerned one notices a clear order from row 1 in the "Forward leaning" cluster to row 5 in the "Upright" cluster (see Figure 2). The further down the paper the children write, the more upright is their position. The same effect appears in relation to dimension 3.

In order to examine interaction effects between row number and pattern we calculated the average co-ordinates of the individual patterns per row. We found that the eccentric position of pattern 2 only occurs when it is written on row 5 (co-ordinates 0·00, −1·10, 0·82, compared to 0·15, 0·35, −0·32 for the first row). For the other patterns the row effect is less strong (e.g., for pattern 4 the co-ordinates for the fifth row are 0·22, −0·22, 0·70). Obviously the pattern and row number effect strengthen each other for pattern 2 on row 5. Behaviours like the ones described in the 2 small clusters in the lower part of the plot are probably characteristic of this pattern when copied at the bottom of the paper. Furthermore, we notice that compared to the row number effect the pattern as

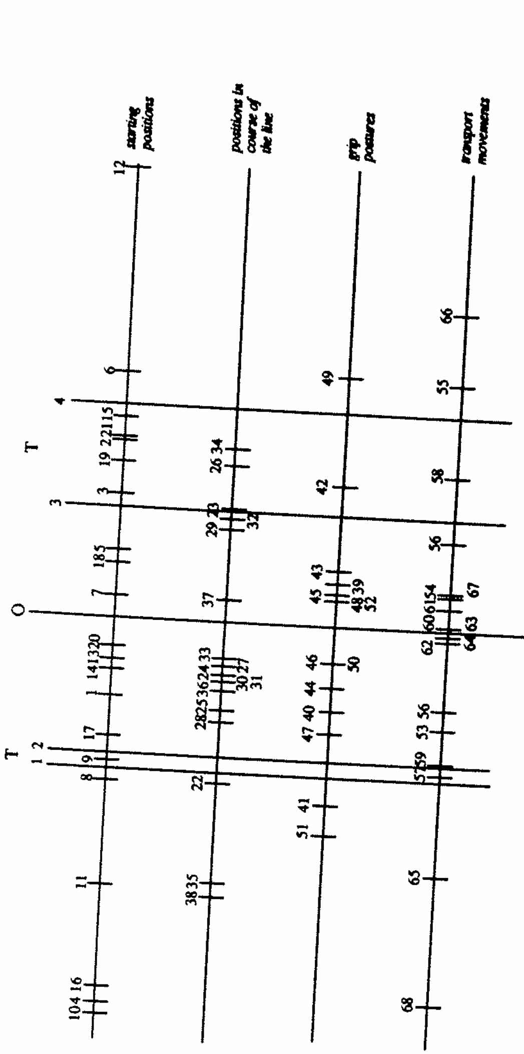

Figure 3. Category quantifications and average time co-ordinates with respect to the first time dimension.

well as the time variable play only a relatively insignificant role in the given structure. This does not necessarily mean that differences in behaviour related to time or pattern can be neglected. Probably the "average" solution is not the best possible one to display these aspects of the data.

Maximizing Time Differences

A different approach to the study of time effects is to analyze another "average data" matrix, namely the time-category matrix of the order of 4 × 68. Again, each element of this matrix is a frequency that specifies how often the group of children used a given category at one of the time points. Homogeneity analysis will then produce quantifications for the 4 time points and the 68 categories. The time point quantifications will show us the relative positions of the time points; the category quantifications will show us which categories are used relatively frequently at which time points.

In the homogeneity analysis of these data the first dimension turned out to be by far the most important one, i.e., it explains much more of the variability of the data than the second dimension. We therefore restrict our attention to this first dimension.

In Figure 3 the relative positions of the different categories on the dimension (i.e., category quantifications) are shown. For better surveyability the data were plotted for each of the 4 groups of items individually. The positions of the time points (i.e., time point quantifications) are given in the same plot. As Figure 3 makes clear, the sequence of the time points on the dimension corresponds to the real sequence. Furthermore, it shows that nothing much happened between T1 and T2. Changes in writing behaviour took place between T2 and T3, and to a somewhat lesser extent between T3 and T4. The nature of these changes will now be described for each group of items individually. (We have checked the following findings by inspecting the frequencies of all categories in time. For lack of space we do not report all these in this paper.)

1. For the *starting position* the most striking change is that of the position of the shoulders (9, 10, 11 vs. 12). This is not surprising, because for T3 and T4 a category "Shoulders cannot be observed" (12) had to be added. (The impression at that moment was that the shoulder line had become less visible because the children lent further forward, their shoulders bent towards the table.) As far as the other items are concerned it shows that with time the trunk is held in a more vertical position (4 vs. 5) and less turned to the left (8 vs. 6, 7). The arm is no longer in whole on the table (1 vs. 2, 3) and the hand lies *under* the line of writing (20 vs. 21). Extension of the wrist occurs less often (17 vs.

the edge of the table (13, 14, 16 vs. 15), smaller and greater distances becoming less frequent.

2. *Positions in the course of the line* change to a more forward leaning posture. The head is held lower (35 vs. 34) and is more often in a turned position (33 vs. 32). The trunk is leaning (30, 31 vs. 29), the shoulders bent forward (27, 28 vs. 26). The position of the forearm becomes more often oblique to the line of writing (36, 38 vs. 37), and the position of the paper perpendicular to the table edge (22, 24, 25 vs. 23).
3. With time the height of the *grip* becomes lower or varies more often (40, 41 vs. 39, 42). The occurrence of tripod postures (44 vs. 43) increases as does that of the grips "Pen rests on the second phalanx of the middle finger" (50 vs. 49) and "Flexion of the index finger" (46 vs. 45). All these phenomena combined suggest that the muscle tension in holding the pencil increases with time. Both "Middle finger on pencil shaft" (51 vs. 52) and "No opposition of thumb and index" (47 vs. 48) become less frequent.
4. *Transport movements* show an increase in whole arm movements (68 vs. 67) together with a "crawling" displacement of the hand (56 vs. 55). Rotation of the forearm (65 vs. 66), recurrent extension of the wrist (53 vs. 54) and "canting" of the hand (57 vs. 58) all decrease.

In short the changes occurring with time can be characterized as a tendency to adopt a more forward leaning posture with only part of the forearm still resting on the table. The muscle tension in holding the pencil seems to increase, while the tripod grip becomes somewhat more frequent. The transport movement is increasingly characterized by a constant leaning of the hand on the table together with whole arm movement.

Maximizing Pattern Differences

The pattern effects were analyzed analogous to the way described for time effects in the preceding section. A homogeneity analysis was carried out on the pattern × category matrix of the order of 4 × 68. The frequencies in this matrix denote how often the group of subjects used a given category per pattern over the 4 time points combined. As the first dimension explains much more of the variability of the data than the next dimensions we only give this one dimension. Furthermore, we restrict ourselves here to a description of the items that concern the transport movement of the arm and hand. These items turned out to be the most discriminating ones, as had also been found at T1 (Blöte *et al.*, 1986). It is evident from Figure 4 that the continuous patterns (3 and 2) are written in a different way than the discontinuous ones (4 and 1). The continuous patterns tend to display a "crawling" progression of the hand (55), recurrent extension of the wrist (53)

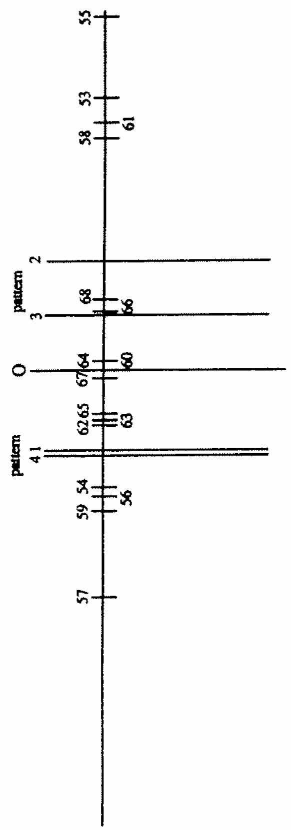

Figure 4. Category quantifications and average pattern co-ordinates with respect to the first pattern dimension (only the transport movement items are plotted).

the wrist (61), while the writing of the letters and circles is more often characterized by a "canting" progression of the hand (57), recurrent lifting of the hand (59) or forearm (63), and rotation of the forearm (65). Finally, we observe that both circles and name/words show the same kind of progression movements, whereas in case of the continuous patterns there is a difference in that the specific "continuous" transport movements are more often made for the zigzags than for the arches.

Discussion

Referring to the research questions put forward in the introduction of this paper we conclude that over a time period of one year some important changes in the writing behaviour of the children have taken place. Those changes predominantly concern shifts in the frequency of occurrence of some behaviours. The interrelationships in the set of observed behaviours do not really change over this time period. That is, the structure of the data as found at T1 (Blöte *et al.*, 1986) is to a large extent also valid at T2, T3, and T4. In a sum analysis of the data of all 4 time points combined the same 2 body posture clusters appear as in the individual analyses, i.e., "Forward leaning" vs. an "Upright" posture. Evidently, body posture is an important discriminating factor in the writing behaviour of children aged 5–7 years. Grip posture is another clearly discriminating variable for children of this age. The grips can be classified into (1) tripod postures, often in combination with too much flexion of the index; (2) grips that are less distal than the tripod grips, i.e., there is no opposition of thumb and index, and/or the pencil rests on the second phalanx of the middle finger instead of on the third; (3) grips that are more distal than the tripod grip, i.e., the tip of the middle finger (and sometimes also of the ring finger) lies on the pencil shaft.

In the changes in writing behaviour over a period of time 2 different tendencies seem at work. In the first place the writing becomes less relaxed: body posture and grip are lowered and show more muscle tension, and the progression of the arm and hand becomes more awkward. This change can be interpreted as an increase of the effort children put into the writing. In doing so they lower their head for better visual inspection of the writing, and increase their muscle tension. This low, forward leaning posture of primary school children has already been described by other (De Ajuriaguerra *et al.*, 1979; Borysowicz and Blöte, 1985; Blöte, Horbach and Van Wijnen, 1986). Secondly, the writing becomes more mature, as is shown by the position of the forearm and hand. Both hand and arm change their position in such a way that the area on the desk that can be used for writing becomes larger (i.e., hand under the line of writing, only part of the forearm resting on the table, and an oblique instead of a parallel position of the forearm). The grips too become more mature, in that the frequency of the tripod grips increases. As to the remark in the T1 paper (Blöte *et al.*, 1986) concerning the high frequency of non-tripod grips however, we have to conclude that this observation still holds for T4. Although the number of tripod grips has increased, deviant grips have still been observed in 40% of the cases. In another study on Dutch children in the first grade of primary school comparable numbers have been found (Blöte *et al.*, 1986). It is likely that most of the children with a deviant grip will never acquire the tripod grip, because after the age of 7 years the grip seems to be independent of age (Ziviani, 1983).

The design of this study does not allow us to go into an interpretation of the just mentioned changes over time. But we suspect that the start of writing instruction between T2 and T3 is an important factor explaining differences between T1 and T2 on the one hand, and T3 and T4 on the other hand. At T3 and T4 the children have learned that their writing product has to meet certain quality demands. The quality demands will increase during the school year as their skill grows. Therefore the effort children put into writing will be greater in the first grade than in kindergarten. Part of the differences between the first 2 time points and the last 2 may, however, also be explained by an observer effect, in that they were scored by different observers. Although the inter-observer agreement between the observers was sufficiently high, any disagreement could be the result of systematic differences between the observers. We think, however, that it is very unlikely that the observer effect plays an important role in explaining the differences. As is evident from Figure 3 the changes between T2 and T3 increase for T4. Since the video recordings at T3 and T4 were observed by the same person in a random order the differences between T3 and T4 cannot be explained by an observer effect, indicating that the differences between T2 and T3 may also show, at least to a large extent, real changes in the writing of the children. Finally, with respect to task effects we conclude that the follow-up measurements of T2 to T4 support the findings of the T1 study, namely that row number influences body posture and that pattern characteristics—continuous vs. discontinuous—are related to progression of hand and arm.

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ALTERATIONS IN LIPIDS AND CARDIORESPIRATORY FUNCTION AFTER WEIGHT TRAINING

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SUMMARY Thirteen healthy, untrained females (mean age, 21 years) were studied to determine the effects of 10 weeks of weight training on serum lipid and lipoprotein levels, cardiorespiratory function and body composition. A control group of eight untrained females (mean age, 21 years) underwent the same evaluation procedures as the training group. Fasting blood samples, collected pre- and post-training, were assayed for triglycerides (TG), total cholesterol (TC), high density lipoprotein cholesterol (HDL-C) and low density lipoprotein (LDL-C). Maximal oxygen uptake (VO_2 max) was determined from a treadmill test. Additionally, body composition was determined by hydrostatic weighing methods. Triglyceride, TC, HDL-C, LDL-C and CHOL/HDL-C were not significantly different among groups. Changes in the experimental group were significantly greater ($p < 0{\cdot}05$) than in the control group for VO_2 max (11·4% vs 2%) and time on a continuous grade-incremented treadmill test (5% vs 1%). Body composition did not change significantly in either group. It was concluded that weight training can improve cardiovascular function independent of changes in serum lipid and lipoproteins.

Key words: Cholesterol, triglyceride, cardiovascular, weight training, female

INTRODUCTION

In recent years, elevated serum levels of total cholesterol (TC), triglyceride (TG), and low-density lipoprotein cholesterol (LDL-C) have been associated with an increased risk of cardiovascular disease

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