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Processing modes of schematic faces in 5- and 10-year-old children

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Kemler Nelson (1984) reported an experiment (Expt 4) intended to demonstrate that the processing of categories evolves with development from a holistic to an analytic mode. Five- and 10-year-old children were asked to learn two categories of schematic faces which were either defined by a single attribute value or structured by overall similarity. As the identification of the children's processing modes was ambiguous, we replicated this experiment, with additional criteria to differentiate between holistic and multi-attribute processing. Results showed that both the 5- and 10-year-old children used an analytic processing mode. The main developmental difference concerned the number of attributes on which their categorization judgements were based. These results can be related to the format of the stimuli.

The major trend in the processing of multidmensional stimuli claims that information processing modes evolve with development, from a holistic to an analytic mode. The holistic mode is defined by the direct perception and representation of the entire object, while the analytic mode requires the extraction of object properties. This view of an individual evolution towards differentiation, accompanied by hierarchical integration, has provided a very general frame for the organization of behaviour (Reuchlin, 1987).

In the domain of perception, this assumption was retained by Gibson (1969) and Vurpillot (1976), who proposed that perceptual development changes from a global to a more abstract and analytic form. In the field of language, the same hypothesis was developed by Werner & Kaplan (1963), and more recently by Keil & Batterman (1984). The former authors supposed that object formation evolves towards a progressive differentiation; the latter considered that word meaning is first based on bundles of characteristic attributes and later on a few defining properties. A similar evolution is found in the classification domain: Inhelder & Piaget (1964) showed a shift from figural collections to non-figural collections and logical classes, Vygotsky (1962) from 'complexes' to concepts. In both cases, a primary conception of the whole is followed by a classification governed by dimensions (see Burns, 1992, for a review).

This article will focus on this issue in the domain of figurative categorization, where similar views are encountered. Some authors (Kemler Nelson, 1984, Expt 4; Smith & Kemler, 1977; Ward, 1980, Expt 3) have shown that young children (kindergarten age) categorize holistically materials for which older children (second and fifth grade) and adults use analytic rules. These findings come mainly from two sorts of experiments: triad classifications, also called restricted classifications, and categorization tasks.

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In the restricted classification task (Garner, 1974), stimuli differ along two dimensions (Fig. 1). Subjects are asked to choose out of each triad the two items that 'go together best'. They can classify either on the basis of dimensional identity (they put together A and B) or on the basis of overall similarity (they group A and C).

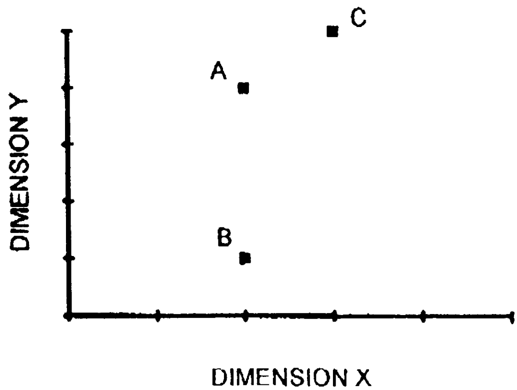

Figure 1. Structure of the stimuli used in the restricted classification task.

This task provided evidence of the influence of a number of factors on processing preferences. First was age: 5-year-old children provided more similarity responses than 8- and 11-year-olds, but with increasing age they make more dimensional groupings (Shepp, Burns & McDonough, 1980; Smith & Kemler, 1977). This was also the case for retarded children as compared to normal (Kemler, 1982) and for impulsive children as compared to reflexive (Smith & Kemler Nelson, 1988). Adults produced similarity responding when asked to classify by their first impressions or when they had to deal with a concurrent task (Smith & Kemler Nelson, 1984).

Finally, when summing up the conclusions stemming from the restricted classification task, the holistic mode is often considered as primitive and linked to immature cognition. It is proposed that children evolve from a holistic resemblance-based processing of objects to an analytic mode based on the identity of attribute values.

Nevertheless, some studies using the same task found opposing results. Wilkening & Lange (1988) pointed out some methodological problems. In particular, they tested a third strategy, at the individual level, which consists in focusing on a single dimension. Using this analytic centration rule, a subject would group together the two items with identical values on this dimension on some occasions and those with close values on this same dimension on other occasions. This would result in dimensional responding in the first case and in similarity responding in the second case. Wilkening & Lange (1988) found that a majority of 5-year-olds' responses fitted this rule. These results weaken the previous conclusions, which were obtained with global data analyses instead of individual ones.

The issue of a developmental trend from holistic to analytic is discussed in the same terms in the domain of figurative categorization. We will focus here on the experimental paradigm elaborated by Kemler Nelson, which gave rise to a number of thoughtful works (Smith & Shapiro, 1989; Sugimura & Inoue, 1987, 1988; Ward & Scott, 1987; Ward, Vela & Hass, 1990). Kemler Nelson asked 5- and 10-year-old children (Expt 4) to learn a pair of highly schematic face categories. From the responses given, she inferred that the younger children rely on family resemblance for categorizing faces whereas older ones tend to use analytic information, which is the inverse trend to that proposed by Carey & Diamond (1977) in the face recognition domain. These authors claim that development proceeds from 'piecemeal' to 'configural' encoding (the switch being at age 10 years) on the basis of data coming from the paradigm of inversion (Carey & Diamond, 1977) and the use of paraphernalia cues such as hats, glasses, etc. (Diamond & Carey, 1977). However, the results of both types of experiments have been challenged at different times, for example by Flin (1985), who concluded that the use of inversion procedures of paraphernalia cues tells us little about children's development of encoding unfamiliar faces.

In Kemler Nelson's experiment, faces were made up of four variable attributes: hair, nose, ears and moustache; eyes were maintained constant across the entire set of stimuli.

Two experimental conditions were contrasted. In the first, called the criterial-attribute problem, one single, necessary and sufficient attribute defined the category membership, whereas in the second, called the family-resemblance problem, there was no defining attribute and category structure relied on the overall similarity between the exemplars. An illustration of the learning exemplars for Category 1 in both conditions is presented in Fig. 2 and the category structure is shown at the top of Table 1.

Figure 2. Learning exemplars of Category I for the criterial-attribute condition (left) and the family-resemblance condition (right).

Values 1 and 2 corresponded to two different values of the same attribute: for instance, curly hair was Value 1 and straight hair Value 2. In the family-resemblance structure (right side of Table 1), 0 was an intermediary value, that is soft hair, which is characteristic of neither category.

In the criterial-attribute condition, the chosen category structure example points out that hair represents the defining attribute, while the other attributes are uninformative. In the family-resemblance condition, the category exemplars are constructed from two prototypes, coded 1 1 1 1 for Category I and 2 2 2 2 for Category II. All the learning exemplars differ from these prototypes by one attribute value.

The task consisted in guessing if the faces belonged to the doctor or the policeman category. Feedback was provided after each answer.

Kemler Nelson's results showed that categorical learning was more difficult for the 5-

Table 1. Example of category structure for the learning exemplars (L1 to L8) and the test exemplars (T1 to T8) in the criterial-attribute condition and the family-resemblance condition. An exemplar is composed of four attributes: Hair (H), nose (N), ears (E) and moustache (M). Each attribute can have three values: 0, 1 or 2. Critical attributes appear in bold

Criterial-attribute				Family-resemblance			
Category I		Category II		Category I		Category II	
	HNEM		HNEM		HNEM		HNEM
L1	**1** 1 1 1	L5	**2** 2 2 2	L1	0 1 1 1	L5	0 2 2 2
L2	**1** 1 2 2	L6	**2** 2 1 1	L2	1 0 1 1	L6	2 0 2 2
L3	**1** 2 1 2	L7	**2** 1 2 1	L3	1 1 0 1	L7	2 2 0 2
L4	**1** 2 2 1	L8	**2** 1 1 2	L4	1 1 1 0	L8	2 2 2 0
T1	**1** 2 2 2	T5	**2** 1 1 1	T1	2 1 1 1	T5	1 2 2 2
T2	**1** 2 1 1	T6	**2** 1 2 2	T2	1 2 1 1	T6	2 1 2 2
T3	**1** 1 2 1	T7	**2** 2 1 2	T3	1 1 2 1	T7	2 2 1 2
T4	**1** 1 1 2	T8	**2** 2 2 1	T4	1 1 1 2	T8	2 2 2 1

year-olds than for the 10-year-olds in the criterial-attribute conditions, while in the resemblance-family condition, younger subjects did as well as the older ones. Kemler Nelson concluded that young children used a holistic processing from the sole results of category learning. According to her, the holistic mode could explain the high performances obtained by 5-year-olds with resemblance-based categories. However, her conclusions are not very convincing because they are based on general learning data such as amount and rate of learning. These indices provide no indication about children's processing modes.

In the criterial-attribute condition, the task resembles concept identification tasks. To learn the categories it is necessary to discover the defining attribute chosen by the experimenter, even if there is no explicit instruction to do so. Kemler Nelson found that 5-year-old children were less efficient than 10-year-olds in identifying this attribute, and this result is entirely compatible with the conclusions stemming from concept identification tasks and showing that logical processes develop with age. Kindergarten children generally use low-level strategies such as stereotypes or attribute-based preferences (Gholson, 1980). They rarely succeed in eliminating disproved hypotheses.

On the contrary, in the family resemblance condition, as category membership is not defined by a single attribute, there are several ways of learning the categories. The first is to consider the overall appearance of the stimuli; the second is to rely on a single attribute and to learn the exceptions (Ward & Scott, 1987); a third may consist in proceeding by a recombination of the previously identified attributes. Only the first processing mode can be qualified as holistic, because stimuli are considered as indivisible entities and judged on their overall similarity to categorical representations. The other two modes correspond to analytic processing based on either one or several attributes.

Kemler Nelson's results have been challenged by Ward & Scott (1987), who replicated this experiment in the family-resemblance condition only and added a test phase. This phase allowed the authors to analyse the subjects' response patterns on new exemplars labelled critical stimuli. These items were those of the learning phase in which the null value was replaced by the opposite category value. An example of the text exemplars is presented at the bottom of Table 1 (T1 to T8 in the family-resemblance condition).

With this modification, the examination of the patterns allows the categorization of single-attribute strategies. If subjects in the family-resemblance condition correctly categorize the items T1 to T3 and T5 to T7, but miscategorize T4 and T8, one can infer that their category membership judgements are based on the values of the fourth attribute (the moustache). Similarly, it is possible to identify any one-attribute strategy. It must be noted that, with this category structure, any attribute chosen as a criterion leads to correct categorization of six out of eight faces.

Ward & Scott (1987) showed that 5-year-old children adopted such an analytic rule as often as adults (about half of them). Their results also suggest that adults picked up information about several attributes, whereas children only noticed the one that governed their categorizations.

Yet another difficulty remains: if the response pattern analysis leads to the identification of simple analytic rules, it does not allow the differentiation of holistic processing and complex analytic rules (Kemler Nelson, 1989) because both strategies provide the correct classification of critical stimuli (e.g. T1, T2, T3 and T4 in Category I, T5, T6, T7 and T8 in Category II).

A previous study (Pacteau, Bonthoux, Perruchet & Lautrey, in press) showed that other behavioural clues can serve to differentiate these two processing modes. In this experiment, Type I patterns which correspond to single-attribute processing were separated from Type II patterns which correspond to resemblance-based categorization. After the test phase, an attribute-identification phase was proposed to 9-year-old children to estimate the amount of acquired categorical information. It was assumed that subjects who based their categorization judgements on several attributes would recognize separate attributes, whereas subjects who processed faces holistically would not. Furthermore, response times have been used as complementary evidence. As analytic strategies are supposed to operate serially, with attributes being processed one after the other, they must lead to longer response times when based on several attributes than when using just one. So, Type II subjects whose response times are longer than Type I subjects should use an analytic multi-attribute strategy instead of a holistic one. Finally, to be classified as holistic, subjects have to present Type II response patterns, with response times no longer than those of single-analytic subjects, and have to be unable to identify separate attributes. Using this procedure, it has been shown (Pacteau *et al.*, in press) that all the 9-year-old children processed schematic faces analytically, relying on one or several attributes.

The purpose of this study is to replicate Kemler Nelson's experiment and reconsider the subjects' processing with these criteria. It is hypothesized that the highly schematic nature of the faces used by Kemler Nelson will favour analytic processing, even in young children in the family-resemblance condition. This prediction is supported by a study using the same kind of stimuli (Sugimura & Inoue, 1987) which showed a predominance of analytic processing with 5- to 6-year-old children at the end of category learning.

Moreover, the comparison of the processing of 5- and 10-year-old children is intended to investigate whether or not a qualitative change occurs with development.

Method

The category formation task used Kemler Nelson's stimuli, which were presented in two experimental conditions: a criterial-attribute condition and a family-resemblance condition. In both conditions, the task was composed of a learning phase, a test phase and an attribute-identification phase. Response times were recorded. During the learning phase, subjects had to categorize faces in two categories (top of Table 1) as rapidly as possible; feedback was provided after each trial. In the test phase using critical stimuli (bottom of Table 1), feedback was omitted. Finally, during the identification phase, subjects had to identify the separate attributes of the two prototypes.

Subjects

Data were collected from 96 children. The younger subjects were 48 children at kindergarten, 22 boys and 26 girls, aged 4 : 8 to 5 : 9 years (mean 5 : 3). The older subjects were 48 fifth-graders, 23 boys and 25 girls, aged 9 : 5 to 10 : 8 years (mean 10 : 3). They were attending classes in public schools in Paris, and came from families of middle socio-economic level. Subjects were randomly assigned to the criterial-attribute or the family-resemblance condition, resulting in 24 children of each age in each condition.

Apparatus and stimuli

The stimuli were generated in the centre of a black and white screen connected to a microcomputer. Two response keys, one for the right hand, one for the left hand, allowed subjects to assign the drawings to one of two categories. Response accuracy and response times were recorded. Both categories were schematic faces, which varied along four independent attributes: hair, nose, ears and moustache. Each attribute could take three different ordered values. During the learning and categorization phases, faces served as stimuli; during the identification phase, the separate attributes (hair, nose, etc.) played this role.

In the *criterial-attribute condition* (left side of Table 1), one attribute had the same value in all the learning exemplars of the same category (1 for Category I, 2 for Category II). Other attributes appeared equally often with value 1 or 2. The defining attribute varied among subjects so that there were four pairs of different categories. For instance, two categories were defined by the nose value, two others by the hair value, etc. Six subjects from each age group were run in each subcondition. The test exemplars were the learning exemplars whose defining attribute value was replaced by the opposite value. In the *family-resemblance condition* (right side of Table 1), category exemplars were transformations of two prototypes which involved a change of one attribute value. In the example provided, prototypes correspond to 1 1 1 1 and 2 2 2 2.

During the learning phase, this changed value was identical for the two categories and took an intermediary value 0. For example, curly hair corresponded to value 1, straight hair to value 2 and soft hair to value 0. During the test phase, the null value was replaced by the opposite category value. Four pairs of categories were derived from four different pairs of prototypes. Six children from each age group were tested in each of these subconditions.

Procedure

The experiment took place in a room of the school where subjects were tested individually. Children sat in front of the screen next to the experimenter. They were told that they would be playing a game with face drawings. They were then instructed: 'Faces will appear on the screen, one by one, and you will have to guess whether they are firemen or policemen. Here is the button for the firemen—the experimenter pointed to one response key—and here is the button for the policemen—the experimenter pointed to the other key. As soon as you have identified a fireman or a policeman, you press the corresponding button. Then I will tell you if you are right or wrong'. For the youngest children, two drawings picturing schematized firemen's or policemen's uniforms stood for the two categories. These uniform drawings were laid close to the keys during the entire experiment. The assignment of the categories to the right or left button and to the firemen or policemen category was counterbalanced through subjects.

Learning phase. Faces appeared successively on the screen. After each key response, feedback was given to the subjects. Stimuli remained on the screen for about 3 s after the children's response. The experimenter could then initiate the next item. The learning phase consisted of four blocks of 12 trials. In each block, the eight learning exemplars (Table 1) were presented at least once in a random order. After two blocks, each learning exemplar had occurred three times.

Test phase. For this phase, the experimenter reiterated the instructions as follows: 'Now new faces will be presented. The game is the same as before. You have to identify the faces as quickly as possible. The only difference is that I won't tell you if your answer is right or wrong'. Stimuli disappeared as soon as a response key had been pressed. Two different random orders of the eight text exemplars, the same for all subjects, were constructed, resulting in a total of 16 trials. Afterwards, the experimenter asked the children how they distinguished between policemen's and firemen's faces.

Attribute-identification phase. The children were given the following instructions: 'I will show you parts of faces. You will try to remember if they belonged to the policemen's or firemen's faces already seen'. Each face attribute appeared successively in the centre of the screen. For each, the children pressed the appropriate key without any time constraint. The eight attributes of the two prototypes (four with the value 1 and four with the value 2) were presented in a random order, identical for all subjects. This procedure was repeated twice. Notice that in the criterial-attribute condition, only the defining attribute could be correctly identified because the other ones were assigned equally often to both categories during the previous phases.

Results

Learning phase

The learning criterion required 11 out of a block of 12 faces to be correctly categorized, with the requirement that this criterion be maintained during the following blocks. Table 2 presents the numbers and percentages of children who reached the learning criterion for both ages and conditions.

Table 2. Learning phase: number (N) and percentage of success with the corresponding mean learning scores (M) and standard deviations (SD) as a function of age and condition

	Criterial-attribute				Family-resemblance			
	N	%	M	SD	N	%	M	SD
5-year-olds	7	29	4.38	1.10	23	96	2.42	1.06
10-year-olds	17	71	3.13	1.45	23	96	2.63	1.01

The number of learners increased with age ($\chi^2 = 5.28$, $p < .05$) across conditions. Independent of age, the learning criterion was achieved more frequently in the family-resemblance condition than in the criterial-attribute condition ($\chi^2 = 10.80, p < .01$). With an equal number of subjects, Kemler Nelson (1984, Expt 4) obtained comparable data: 10 and 18 succeeded in the criterial-attribute condition respectively at 5 and 10 years old, 20 and 20 succeeded in the family-resemblance condition. So, during this phase, which replicated Kemler Nelson's experiment, our results were identical to hers. The young children were less successful than the older ones in learning the well-defined categories, while they showed equally good performances with the family-resemblance categories.

As mentioned previously, the 24 subjects of each group were divided into four subgroups, for which the criterial attribute or the prototypes differed. In the criterial-attribute condition, learning was unequally distributed across the subgroups. In particular, the 'ear-defined categories' were the most difficult to learn, suggesting that this attribute was less salient than the others. In the family-resemblance condition, there were no differences between the subgroups. Learning speed was operationalized by the number of blocks necessary to achieve the learning criterion (scores from 1 to 4). Non-learners were credited a score of 5. Lower scores corresponded to higher performances.

Table 2 shows the means and standard deviations of learning scores for the four groups of subjects. An analysis of variance with age and condition as between-subject variables showed main effects of age ($F(1,92) = 4.76$, $p<.05$), and condition ($F(1,92) = 26.54$, $p<.0001$), and a significant interaction ($F(1,92) = 9.34$, $p<.01$). Specific comparisons indicated that 10-year-old children had better performances than 5-year-olds only in the criterial-attribute condition ($F(1,46) = 11.31$, $p<.01$). Moreover, the advantage for the family-resemblance condition was only significant for the younger children ($F(1,46) = 39.60$, $p<.0001$). When only the learners were considered, the same analysis showed no effects of age or condition, nor an interaction. For the learners, the learning criterion was reached after a mean of 2.44 blocks of trials (SD = 0.92).

Test phase

Classifiable subjects were those who committed no more than four errors out of 16 items. This error rate corresponds to random responding with a binomial probability of less than .05 ($p = .038$).

Criterial-attribute condition. Of the 24 subjects who reached the learning criterion, three children (one kindergarten and two fifth-graders) failed the test phase, while the others made very few errors (0 or 1).

On the contrary, two additional children of each age group discovered the categorization rule during the test phase: they miscategorized no more than one face out of the 16 test exemplars (the probability of providing such a pattern with random responding is less than .001). Consequently their responses will be included in the following analyses.

In summary, eight subjects among the younger children and 17 subjects among the older applied the analytic categorization rule during the test phase. The differences between subgroups increased *vis-à-vis* the learning phase. The most difficult categorization involved the rule governed by the ears attribute. On the other hand, the task was easier when hair was the defining attribute. Finally, it can be noted that all the older children could verbally explain their strategies, whereas only one younger child (out of eight) was able to do so. Nevertheless, of the subjects who did not mention the necessary and sufficient attribute, nobody cited an incorrect feature.

Family-resemblance condition. The same test criterion was used. Subjects had to produce 12 correct responses out of 16. However, what were considered as errors differed according to the response patterns.

If the same attribute was responsible for three or four miscategorizations, the pattern was labelled as Type I. This pattern showed that face processing was based upon the values of a sole attribute, named the focus attribute. In this case, wrong responses were those that differed from the strict Type I pattern. Therefore, Type I learners were subjects who gave no more than four responses different from the strict Type I pattern, with the restriction that no more than two errors occurred on a secondary attribute.

If subjects presented no errors or errors distributed among several attributes, their pattern was labelled as Type II. Type II learners were subjects who performed no more than four miscategorizations, with the additional constraint that no more than two errors were governed by the same attribute. Other patterns were considered unclassifiable.

Of the children who succeeded in the learning phase (23 in each age group), at five years 17 were of Type I and six of Type II, whereas at 10 years there were respectively 15 and seven (one was unclasssifiable).

The proportion of Type I subjects was much higher than that of Type II for both groups. This pattern, indicating an analytic strategy based on a single attribute, was observed for almost three-quarters of the 5-year-old children. Among the Type I subjects, eight 5-year-olds and nine 10-year-olds did not make any error, while there was no perfect Type II pattern.

The only kindergarten child who failed during the learning phase elicited a perfect analytic strategy during the test phase. The attribute he chose as a classification base (the nose) was the one that was mainly responsible for errors during the last blocks of the learning phase. On the other hand, the only fifth-grader who failed during the learning phase failed the test too. The number of subjects identified as using the attributes of hair, nose, ears and moustache were 8, 5, 0 and 4, respectively, for the Type I kindergarten children and 3, 4, 2 and 6 for the Type I fifth-graders. Thus, for both groups, the least frequently chosen attribute was ears.

According to the verbalizations, the Type I subjects who explained their categorizations by means of one attribute mentioned the attribute that effectively supported their decisions. This was the case for all the 10-year-old children and about half of the 5-year-olds (eight out of 17). For the Type II subjects, four out of six 5-year-old children cited one attribute responsible for the errors in the test phase. All the older Type II subjects mentioned at least two attributes to explain their strategies.

Response times

Table 3 indicates that the 10-year-old children responded faster than the 5-year-olds and that categorization was overall slower in the family-resemblance condition than in the criterial-attribute condition.

Table 3. Subject number (*N*), means (*M*) and standard deviations (SD) of response times (in milliseconds) as a function of age, condition and type of pattern

	Criterial-attribute			Family-resemblance		
	N	*M*	SD	*N*	*M*	SD
5-year-olds	8	1395	354	23	1923	593
10-year-olds	17	1189	502	22	1606	528

An analysis of variance was conducted on the logarithms of the response times. It showed a significant effect for age ($F(1,67) = 14.68$, $p<.001$), and condition ($F(1,67) = 15.67$, $p<.001$), and no interaction.

In the criterial-attribute condition, subjects had to process a sole attribute while ignoring the other irrelevant ones. Thus, the localization of this attribute, always situated in the same place, could explain the fast response times. On the contrary, in the family-resemblance condition, all the attributes were partially informative. The longer response times could be explained by a process that took into account several attributes. As it is generally considered that multi-attribute processing operates sequentially, a longer time is required than in one-attribute processing. So the assumption is that some subjects in the family-resemblance condition may have employed this type of processing.

Table 4 shows the response times of Type I and Type II subjects in the family-resemblance condition. An analysis of variance on the transformed response times, with Type (I and II) and age (5 and 10 years) as between-subject variables, showed that the younger children were slower than the older ones, ($F(1,42) = 6.03$, $p<.05$), but indicated no significant difference between the Type I and Type II subjects. Only the strict Type I subjects, who committed no errors during the test phase, were faster than the others: respectively 1556 ms and 2110 ms for the kindergarten children, 1505 ms and 1676 ms for the fifth-graders ($F(1,42) = 4.40$, $p<.05$). This result means that, except for the subjects who based their categorization exclusively on one main attribute, the other children may have relied on several. To determine which information has been retained, the results of the identification phase should be examined.

Table 4. Family-resemblance condition: number (N), mean test response times (in milliseconds) and identification scores for both types of response as a function of age

	Type I			Type II		
	N	Response time	Identification score	N	Response time	Identification score
5-year-olds	17	1953 (SD = 354)	10.61 (SD = 2.64)	6	1903 (SD = 593)	11.50 (SD = 3.39)
10-year-olds	15	1556 (SD = 502)	11.40 (SD = 2.64)	7	1771 (SD = 528)	12.86 (SD = 1.46)

The identification phase. Remember that in the *criterial-attribute condition*, only the defining attribute represented by four instances could be assigned correctly. Among the classifiable subjects, all were able to categorize the attribute values correctly when they were presented outside the face context. No fifth-graders and only two kindergarten children made one incorrect identification (out of four, that is 6 per cent of miscategorizations for this group).

In the *family-resemblance condition*, the identification score was the number of attributes identified correctly (out of 16). As shown in Table 4, this score seemed globally higher for the older children compared with the younger, and for the Type II subjects compared with the Type I. However, no significant effect was found by means of analysis of variance.

All the mean scores were significantly higher than a score obtained with random responding (=8). For instance, for the lowest score, namely 10.61, $t(16) = 4.08$, $p<.01$. This result supports the assumption made after the response time analysis. All the 5- and 10-year-old children had acquired some knowledge about face attributes. In particular, the score of the Type II subjects excludes the inference of holistic processing for this group.

Type I subjects recognized correctly the four instances of the main attribute on which their categorization strategy was based (94 and 95 per cent of correct identifications respectively for the 5- and 10-year-old children). To know whether they identified some secondary attributes, the number of correct assignments for the non-focused attributes was calculated (score out of 12) and was compared with random responding (=6). For the older subjects, this score exceeded 6 significantly ($t(14) = 2.39$, $p<.05$), whereas it was not the case for the younger ones ($t(16) = 1.25$, $p>.10$). This result showed that the 10-year-old children, in contrast to the 5-year-olds, encoded and retained some knowledge about attributes which did not serve as a decision base. Moreover, the ears were the least identified attribute. The mean scores for this attribute were respectively 1.9 and 2.4 (out of 4) for the kindergarten children and the fifth-graders. These scores did not differ from random responding, while this was the case for the scores of the three other attributes (for each score, $p<.02$). These scores ranged form 2.8 for the nose for the youngest subjects to 3.6 for the moustache for the oldest ones.

Relation between test phase and identification phase

Previous results showed that all children obtained relatively high identification scores. Could this acquired knowledge have influenced their categorization decisions? To answer this question, correlation coefficients were calculated for each attribute between the number of errors for which this attribute was responsible in the test phase and the attribute identification score.

For the Type I subjects, these coefficients were .47 ($N = 68$, N being the number of pairs of values included in the coefficient calculation) and .39 ($N = 60$) for the 5- and 10-year-old children respectively; for the Type II subjects, they were .43 ($N = 24$) and .40 ($N = 28$). All the correlation coefficients, although not very high, were significant ($p<.05$). This means that an attribute that prompted errors is more likely to be identified. It then appears that attribute knowledge was used during the categorization task, so another assumption can be made. If more time is necessary to consider several attributes than a single one, the identification score should be correlated with the response times. The correlation coefficients between these two measures were .57 ($p<.05$) for the 5-year-old children and .35 ($p = .05$) for the 10-year-olds. This result supports the hypothesis that all subjects used an analytic mode, relying on one or several attributes.

Discussion

With regard to the overall learning performance, our results replicated those of Kemler Nelson (1984, Expt 4). The kindergarten children showed more difficulties in learning the well-defined categories than the resemblance-based categories. They were also less efficient than the fifth-graders judged by the number of successes and the learning rate.

In the criterial-attribute condition, learners discovered the categorization rule imposed by the experimenter and were able to transfer it to new test exemplars even at the age of 5. Three learners seemed to be troubled by these new exemplars and committed numerous errors during the test phase. Their success in the learning phase may have rested only on the storage of the eight learning exemplars. In this case, they would not have been able to extract and then transfer the analytic rule to previously unseen exemplars.

The family-resemblance condition was constructed to analyse the children's preferred strategies. The subjects' classification as a function of their test response pattern indicated that a majority of children chose a single attribute and used it as a decision base. This conclusion is strongly supported by the nearly perfect identification score demonstrated by the Type I subjects for this attribute. These results testify that the one-attribute grouping predominated among subjects, whether they were 5 or 10 years old. They run counter to Kemler Nelson's findings and can easily be explained by the fact that this author was not in a position to analyse the children's strategies because her experiment did not comprise a test phase.

For the Type I subjects, the only developmental difference observed concerns the amount of information acquired about the face attributes. The older subjects possessed some knowledge about secondary attributes, which was not the case for the younger ones. For the Type II subjects, the attribute identification score was relatively high for both groups of subjects. This result invalidates the assumption of holistic processing because this processing mode would not allow subjects to extract and thus identify isolated attributes. The alternative view supposes that the Type II subjects relied on the overall similarity between exemplars, but that similarity resulted from a sequential computation of several attribute values. This interpretation is supported by the relations observed between the test and identification phases. First, the categorization errors corresponded partly to well-recognized attributes and, second, the number of identifications was positively correlated with the processing time of test exemplars.

Therefore, all the subjects processed analytically, whether they were Type I or Type II, 5 or 10 years old. The differences between them are related to the number of elements included in their categorical judgements. Strict Type I subjects depended mainly on a single attribute while other Type I and Type II subjects relied on several. The developmental differences concerned processing efficiency. Older subjects were faster and stored more attribute knowledge than younger ones.

It is legitimate to conclude that 5-year-old children are disadvantaged compared to the 10-year-olds when the defining attribute is set by the experimenter. The analytic processing used by the young children shows an inflexible way of functioning and does not allow them to change a hypothesis when disproved. This conclusion agrees with concept identification results (Gholson & Beilin, 1979) where the concept is defined by the experimenter. On the contrary, when young children can choose the attribute on which they base their decisions, they are capable of analytic processing as often as older subjects. In the family-resemblance condition, where the choice of every attribute as a criterial one leads to category learning, young children's success was almost total, while in the criterial-attribute condition only one-third succeeded.

On the one hand, no holistic-to-analytic shift has been observed on our task and similar results were obtained by Wilkening & Lange (1988) with the restricted classification task. If this developmental change exists, it may occur earlier: it would therefore be necessary to test children younger than 5 to observe such a change. Nevertheless, some studies indicate that very young children are able to detect some object dimensions that direct their judgements. For example, Macario, Shipley & Billman (1990) showed that 4-year-old children considered objects by relying on their component attributes, instead of their similarity relations. The results of Landau, Smith & Jones (1988) also suggest that children, even 2-year-olds, attend selectively to some dimensions. On the other hand, the analytic-to-holistic hypothesis proposed by Carey & Diamond (1977) deserves to be tested in figurative categorization.

Our results do not rule out the differentiation hypothesis, because situational factors could have interacted with developmental factors. In fact, we assume that the very schematization of face drawings favours their processing in component elements. Thus, when a less separable material is proposed, holistic processing can be used independently of age level. Pacteau (submitted) showed that half of 9-year-old children categorized photographs of faces holistically and Cooper (1982), with similar stimuli, provided evidence of adults' holistic processing in a discrimination task.

Our point of view is that, at every age of life, each individual possesses both processing modes, which are elicited with more or less facility according to factors such as age, preference or situation (Lautrey, 1990). According to this view, the plurality of processing modes is considered as an adaptative advantage.

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References

Burns, B. (1992). Perceived similarity in perceptual and conceptual development: The influence of category information on perceptual organization. In B. Burns (Ed.), *Percepts, Concepts and Categories*. Amsterdam: Elsevier.

Carey, S. & Diamond, R. (1977). From piecemeal to configurational representation of faces. *Science*, **195**, 312–314.

Cooper, L. A. (1982). Strategies for visual comparison and representation: Individual differences. In R. J. Sternberg (Ed.), *Advances in the Psychology of Human Intelligence*, vol. 1, pp. 77–124. Hillsdale, NJ: Erlbaum.

Diamond, R. & Carey, S. (1977). Developmental changes in the representation of faces. *Journal of Experimental Child Psychology*, **23**, 1–22.

Flin, R. H. (1985). Development of face recognition: An encoding switch? *British Journal of Psychology*, **76**, 123–134.

Garner, W. R. (1974). *The Processing of Information and Structure*. Potomac, MD: Erlbaum.

Gholson, B. (1980). *The Cognitive Developmental Basis of Human Learning: Studies in Hypothesis Testing*. New York: Academic Press.

Gholson, B. & Beilin, H. (1979). A developmental model of human learning. In H. W. Reese & L. P. Lipsitt (Eds), *Advances in Child Development and Behavior*, vol. **13**, pp. 47–81. New York: Academic Press.

Gibson, E. J. (1969). *Principles of Perceptual Learning and Development*. New York: Appleton-Century Crofts.

Inhelder, B. & Piaget, J. (1964). *The Early Growth of Logic in the Child*. New York: Norton.

Keil, F. C. & Batterman, N. (1984). A characteristic-to-defining shift in the development of word meaning. *Journal of Verbal Learning and Verbal Behavior*, **23**, 221–236.

Kemler, D. G. (1982). Classification in young and retarded children: The primacy of overall similarity relations. *Child Development*, **53**, 768–779.

Kemler Nelson, D. G. (1984). The effect of intention on what concepts are acquired. *Journal of Verbal Learning and Verbal Behavior*, **23**, 734–759.

Kemler Nelson, D. G. (1989). The nature and occurrence of holistic processing. In B. E. Shepp & S. Ballesteros (Eds), *Object Perception: Structure and Process*. Hillsdale NJ: Erlbaum.

Landau, B., Smith, L. B. & Jones, S. S. (1988). The importance of shape in early lexical learning. *Cognitive Development*, **3**, 299–321.

Lautrey, J. (1990). Esquisse d'un modèle pluraliste du développement cognitif. In M. Reuchlin, J. Lautrey, C. Marendaz & T. Ohlmann (Eds), *Cognition: l'universel et l'individuel*, pp. 185–216. Paris: PUF.

Macario, J. F., Shipley, E. F. & Billman, D. O. (1990). Induction from a single instance: Formation of a novel category. *Journal of Experimental Child Psychology*, **50**, 179–199.

Pacteau, C. (submitted). Categorization: When is there an holistic mode of processing? *Current Psychology of Cognition*.

Pacteau, C., Bonthoux, F., Lautrey, J. & Perruchet, P. (in press). Category learning of schematic faces in children: Relationships between attribute-knowledge and modes of processing. *International Journal of Psychology*.

Reuchlin, M. (1987). Différenciation, intégration hiérarchique, genèse, *Bulletin de Psychologie*, **381**, 703–722.

Shepp, B. E., Burns, B. & McDonough, D. (1980). The relation of stimulus structure to perceptual and cognitive development: Further tests of a separability hypothesis. In F. Wilkening, J. Becker & T. Trabasso (Eds), *Information Integration by Children*. Hillsdale, NJ: Erlbaum.

Smith, J. D. & Kemler Nelson, D. G. (1984). Overall similarity in adults' classification: The child in all of us. *Journal of Experimental Psychology: General*, **113**, 137–159.

Smith, J. D. & Kemler Nelson, D. G. (1988). Is the more impulsive child a more holistic processor? A reconsideration. *Child Development*, **59**, 719–727.

Smith, J. D. & Shapiro, J. H. (1989). The occurrence of holistic categorization. *Journal of Memory and Language*, **28**, 386–399.

Smith, L. B. & Kemler, D. G. (1977). Developmental trends in free classification: Evidence for a new conceptualization of perceptual development. *Journal of Experimental Child Psychology*, **24**, 279–298.

Sugimura, T. & Inoue, T. (1987). Role of classification training on children's categorization. *Psychologia*, **30**, 61–69.

Sugimura, T. & Inoue, T. (1988). Factors affecting analytic and holistic modes in children's classification learning. *Perceptual and Motor Skills*, **66**, 723–736.

Vurpillot, E. (1976). *The Visual World of the Child*. New York: International Universities Press.

Vygotsky, L. S. (1962). *Thought and Language*. Cambridge, MA: MIT Press.

Ward, T. B. (1980). Separable and integral responding by children and adults to the dimension of length and density. *Child Development*, **51**, 676–684.

Ward, T. B. & Scott, J. (1987). Analytic and holistic modes of learning family-resemblance concepts. *Memory and Cognition*, **15**, 42–54.

Ward, T. B., Vela, E. & Hass, S. D. (1990). Children and adults learn family-resemblance categories analytically. *Child Development*, **61**, 593–605.

Werner, H. & Kaplan, B. (1963). *Symbol Formation. An Organismic-Developmental Approach to Language and the Expression of Thought*. New York: Wiley.

Wilkening, F. & Lange, K. (1988). When is children's perception holistic? Goals and styles in processing multidimensional stimuli. In T. Globerson & T. Zelnicker (Eds), *Cognitive Style and Cognitive Development*. Norwood, NJ: Ablex.

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