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Representational flexibility in children's drawings: Effects of age and verbal instructions

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This study aims to investigate representational and syntactical flexibility in children's drawing behaviour, and the extent to which changes introduced at both representational and syntactical levels are related to age or can be induced by contextual manipulations. A Deletion task required three age groups of 5-, 7- and 9-year-old children to draw objects that had been rendered partially invisible, thanks to magic transformations. Two different verbal instructions about what was to remain visible in the objects, and two different objects, one regularly and one non-regularly drawn, were designed to investigate contextual sensitivity in children's representational and syntactical behaviour respectively. The results provided evidence for sequential-like developments with regard to both representational and syntactical flexibility in children. The extent to which the procedural constraints of drawing prevented representational flexibility to be expressed was investigated in a second experiment, in which the deletions were performed by means of an eraser on pre-printed 2D line drawings. The results showed that the expression of representational flexibility across ages did not fundamentally change as a function of the load imposed by the procedural constraints.

Human beings have a variety of ways of representing features of the world to themselves and drawing illustrates one of the various types of external notation created by the human 'print-out facility' (Wilks, 1982). Because drawing leaves an intentional trace that can be recognized as symbolizing categories of objects, it has been conceived of as a 'public instrument of representation' (Freeman, 1993), where the iconic relationships between the symbol and the reality it refers to may sometimes be prototypical (e.g. the canonical drawing of a house) and sometimes conventional (e.g. a heart with an arrow for love). In both cases, drawing usually becomes quite rigid, whether it is the trace left on the paper or the motor sequence used for drawing that is considered. Drawing is also, however, a profoundly rich and creative means of symbolically representing events, objects and feelings, and it is open to many types of innovations. Innovations can be introduced in the internal graphic image used for producing the external graphic trace, as well as in the executive motor aspects of drawing. The former are indicative of conceptual flexibility, the latter of motor or 'syntactical' (Goodnow & Lévine, 1973) flexibility. Drawing is a symbolic output that results from influences and constraints exerted at these two levels—

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conceptual and motor—and has consequently been used, in the literature, as a tool for assessing both cognitive representations and psychomotor functioning.

There has been considerable debate regarding the extent to which children's drawings can be used as data for studying internal representations (Freeman, 1980, 1987; Kosslyn, Heldmeyer & Lockear, 1977; Laszlo & Broderick, 1985; Olson & Bialystok, 1983). Drawing can be used to some extent to reveal internal representations, but certainly not in a simple and direct way. To argue that symbolism in drawings directly reflects the underlying cognitive representations is indeed quite absurd, given the disparity between the content of children's drawings and their knowledge about various topics. In contrast, the relationships between drawing and psychomotor functioning seem more direct, and can be observed at a more or less global level, in movement sequencing, movement accuracy or movement timing, for instance (e.g. Van Sommers, 1984; Meulenbroek & Thomassen, 1993).

This study deals with flexibility in children's drawing behaviour studied at both conceptual and syntactical (movement sequencing) levels. Numerous studies have shown that the flexibility demonstrated by children in drawing is limited, although not absent, at the two levels.

With regard to conceptual or representational flexibility, children's ability to produce representational changes under task conditions (e.g. 'drawing a house that does not exist'; Karmiloff-Smith, 1990) seems to evolve from an intra-representational level to an inter-representational level. At 4–5 years, the innovations are restricted to a single graphic representation (e.g. changing the shape of the house), while at 9–11 years they are based on the introduction of elements pertaining to a different graphic representation (e.g. addition of birdwings to the house). Further evidence for such a sequential evolution was provided by Vinter & Picard (1996), using a similar innovation task. The authors also showed that, from 5 to 7 years of age, changes performed at the intra-representational level extended from individual elements to the whole graphic representation. Understanding flexibility requires one to focus on the process which insures the appropriate accommodation of subjects to novel tasks. To provide further insight into representational flexibility in children, a novel drawing task was therefore designed. This is a Deletion task which requires children to draw objects that have been rendered partially invisible, thanks to magic transformations. A similar task has already been used with a small number of children in Vinter & Picard (1996). Similarly, Berti & Freeman (1997) analysed free deletions in 5- and 9-year-old children by requiring them to draw 'a person with something missing'. They investigated the extent to which children deleted more than they verbally reported to the experimenter, and analysed the moment at which the deletion was performed in the course of the routine. Age effects were found with regard to the amount of information deleted in the drawing when compared to that verbally reported by children: young children deleted more than they claimed. The present study aims to investigate thoroughly children's drawing behaviour in a Deletion task, in terms of the types of deletions introduced in a drawing rather than in terms of amount of deletion. By means of the requirements of the Deletion task, the children were forced to modify their internal representations of familiar objects through an analysis of the internal symbolic contents of their graphic representations. This analysis may involve different processes, a decomposition of the representation into parts, a sampling of elements for instance. In line with Karmiloff-Smith's (1990) study and Vinter & Picard's

(1996) study, age-related representational changes can be expected. The youngest children are expected to tend to delete elements or to sample the graphic representations, and the older children to delete parts of the whole graphic representation.

With regard to motor flexibility, the organization of graphic movements appears to be highly structured by a set of graphic rules (Goodnow & Lévine, 1973; Van Sommers, 1984) which refers to the selection of a starting location for each graphic segment (e.g. at the top), to the choice of a movement direction or progression (e.g. from left to right), and to the global ordering of the elementary movements forming the drawing sequence (e.g. anchoring the next segment to the one drawn previously). Developmental trends have been reported in the way the graphic rules are obeyed (Minary & Vinter, 1996; Nihei, 1983; Ninio & Lieblich, 1976; Thomassen & Teulings, 1979; Vinter, 1994). Moreover, it has been suggested that a compiled procedure that encapsulates knowledge in a fixed sequence of movements could account for drawing (Karmiloff-Smith, 1990, 1992). Nevertheless, evidence from several experimental studies showing that children's graphic routines are not as rigid as Karmiloff-Smith had suggested (Spencer, 1990, 1995; Van Sommers, 1984) led the author to abandon the very specific concept of compiled procedures in drawing (Karmiloff-Smith, 1992). The general framework for drawing developed by Freeman (1980, 1993) also provides a strong motivation to cast doubt on the idea that drawing is rigid. In the present study, the conceptual reorganization of the graphic representations imposed by the deletion task is necessarily accompanied by changes at the executive level: children have to interrupt the course of their ongoing drawing activity (their graphic routines) in order to omit the production of certain graphic traces of the depicted object. Previous studies have shown that flexibility at the procedural level is already present at 5 years, as indicated by children's ability to introduce changes at the beginning as well as at the end of their graphic routines (Berti & Freeman, 1997; Vinter & Picard, 1996; Zhi, Thomas & Robinson, 1997), but continues to develop up to age 9 years when interruptions performed at the end of the graphic routines disappear (Vinter & Picard, 1996). On the basis of these data, it is assumed here that the deletions will be preferentially performed at the end of the graphic routines at 5 years, and at the beginning later.

Age-related changes at both the representational and syntactical levels of children's drawing behaviour can thus be expected. However, it is interesting to ask the extent to which these developmental sequences are sensitive to contextual manipulations. Large amounts of data in the literature have shown how much of children's drawing behaviour is context-dependent (e.g. Barrett & Bridson, 1983; Barrett, Beaumont & Jennett, 1985; Beal & Arnold, 1990; Cox, 1981, 1985, 1992; Davis, 1983; Light & McEwen, 1987), thus severely limiting the possibility of the existence of a sequential cumulative progression in drawing development. In the present study, contextual manipulations are again introduced at both the conceptual and syntactical levels. At the conceptual level, two different verbal instructions about what remains visible in the object are used, one mentioning that only 'pieces' of the objects are still visible, the other speaking of 'parts'. Insofar as intra-representational changes have been shown to be first 'element-based' then 'whole-based' (Vinter & Picard, 1996), using the 'pieces' and 'parts' verbal instructions should allow one to test the extent to which changes considered typical as of a given age can be induced in younger or in older children. In accordance with the idea that a sequential evolution characterizes children's ability to perform intra-representational changes, children's sensitivity to the 'pieces' and 'parts' verbal instructions should be limited at ages 9 and 5 years respectively. At the syntactical level, an appropriate context manipulation appears to elicit either a well-established graphic routine or a rarely produced graphic sequence. The children were therefore required to delete pieces or parts from two different objects, a house and a television. Although both objects are familiar, only the house, which is regularly drawn, gives rise to well-established graphic routines, introducing a higher degree of rigidity in movement sequencing. It was expected that the house would lead children to display more rigid graphic routines than the television; however, no difference in terms of types of representational changes introduced in the drawings should appear between the two objects. Rigidity at the procedural level should not prevent the expression of flexibility at the representational level in children's drawings.

In order to investigate this last hypothesis further, a second experiment was conducted in which children had to use an eraser to delete information (pieces or parts) on pre-printed 2D line drawings. This deletion procedure strongly reduces the procedural constraints of drawing activity involved in the first experiment. No major differences in terms of representational changes should emerge from the use of these two different procedures of deleting from drawings. However, if some representational changes are really restricted by strong procedural constraints present in drawing, the second deletion procedure should facilitate their emergence.

EXPERIMENT 1

Method

Participants

Sixty children, divided into three age groups of 20 children each, were observed: 5 years (mean age = 5.28; 10 girls and 10 boys), 7 years (mean age = 7.35; 9 girls and 11 boys), and 9 years (mean age = 9.42; 11 girls and 9 boys). None of these children had psychomotor deficits with regard to drawing or handwriting. They were observed individually in a quiet room inside their school.

Material

Two familiar objects, a house and a television, were used. They were selected because of their common basic rectangular structure (the body), which could be enriched by both internal (e.g. window, knobs) or external (e.g. chimney, aerial) elements. Only the first object, the house, triggered well-established graphic routines in children, being a regularly drawn object. Children made their drawings on separate white sheets of paper (size 21 × 14.8 cm) with a normal pen.

Procedure

Children had to draw the selected objects in two successive tasks. The first task (Free-drawing task) required them to draw the objects in an evocation condition, that is without any model at their disposal, but in response to verbal naming. They were simply asked, 'Please draw me a house', for instance. Once the task was completed, the experimenter told the children that a magician had tried to make the objects invisible, but had failed because he could not remember his magic formula properly. The objects were finally only partially invisible. Two verbal instructions were then given. Half of the children of each age group was instructed that 'We only see a few bits of it', whereas the other half received the instruction that

'We can't see all of it any more'. It is worth pointing out that the wording used in French for the second verbal instruction is more accessible to a French 5-year-old child than the English translation would be to an English native 5-year-old[1]. Children did not encounter problems in understanding the two verbal instructions. These two verbal instructions were labelled 'pieces' and 'parts' respectively, because of the size of the representational units they should *a priori* lead children to work on. The children were required to draw what would remain visible of the objects (Deletion task). The order in which the tasks were presented was kept constant for all the subjects (Free-drawing task, then Deletion task), because the Free-drawing task, which allowed us to establish baseline data, logically had to be presented first. The order in which the objects were presented was counterbalanced between children and tasks. No feedback or comment was given while the children produced their drawings. The experiment was conducted individually and lasted between 10 and 20 min, depending on the child. A second experimenter was trained to code online the starting points, movement directions, and the order in which the segments were laid down on the paper. The complete sequence of the movements performed was thus encoded. Moreover, the complete experimental session was video-recorded for each child. The online coding of the children's drawing sequences was therefore checked offline with the video recordings. Only a few errors were detected (2%) and corrected before the data analysis.

Results

Flexibility at the symbolic level was inferred from an analysis of the types of deletion made by children in their drawings. The deletions were identified with reference to the drawings produced in the baseline (Free-drawing) task. Flexibility at the syntactical level was investigated by comparing different aspects of the graphic sequences used by the children in the Free-drawing task with those used in the Deletion task.

Representational flexibility: Types of deletion and effects of the verbal instructions

Close examination of the children's end-products revealed that four types of deletions were sufficient to categorize the whole set of data. Two independent judges coded the 120 collected drawings with reference to these four categories, and an overall percentage of 87.5% agreement was obtained. Disagreements were settled before analysing the data. Categories of deletion are illustrated in the top part of Figure 1 for the house drawing condition. A first category of deletion corresponded to a very crude breakdown of the object into its constituent elements. The drawings were restricted to a very small number of features, constituting indices of the whole object, but not always sufficient to guarantee its unambiguous identification.[2] A second type of deletion corresponded to a reduction of the representation: some elements of the object were missing but not the most important, so that the object could still be easily recognized. A third category of deletion involved a decomposition of the representation: the object was split into two parts about a vertical or horizontal axis, so that one part of the object remained visible, while the other was neglected. Finally, the whole representation was fragmented so that the object appeared in dotted lines. Traces of elements were omitted at more or less regular intervals by lifting the pen, but the whole object could still be easily recognized as a house or a television. Figure 1 shows the frequency of occurrence of these categories of deletion performed in response to the 'pieces' and 'parts' verbal instructions as a function of age. A series of

[1] The precise instructions in French were: 'On ne voit que quelques morceaux de l'objet' and 'On ne voit pas l'objet tout entier'.
[2] Verbal comments produced by the children in the course of their drawing were used to identify the elements reported.

ANOVAs[3] was carried out with Age (3) and Verbal Instruction (2) as between-subjects factors, and Object (2) as a within-subject factor on the frequency of occurrence of each category of deletion. No significant effect of the object was recorded ($F < 1$), whatever the type of deletion.

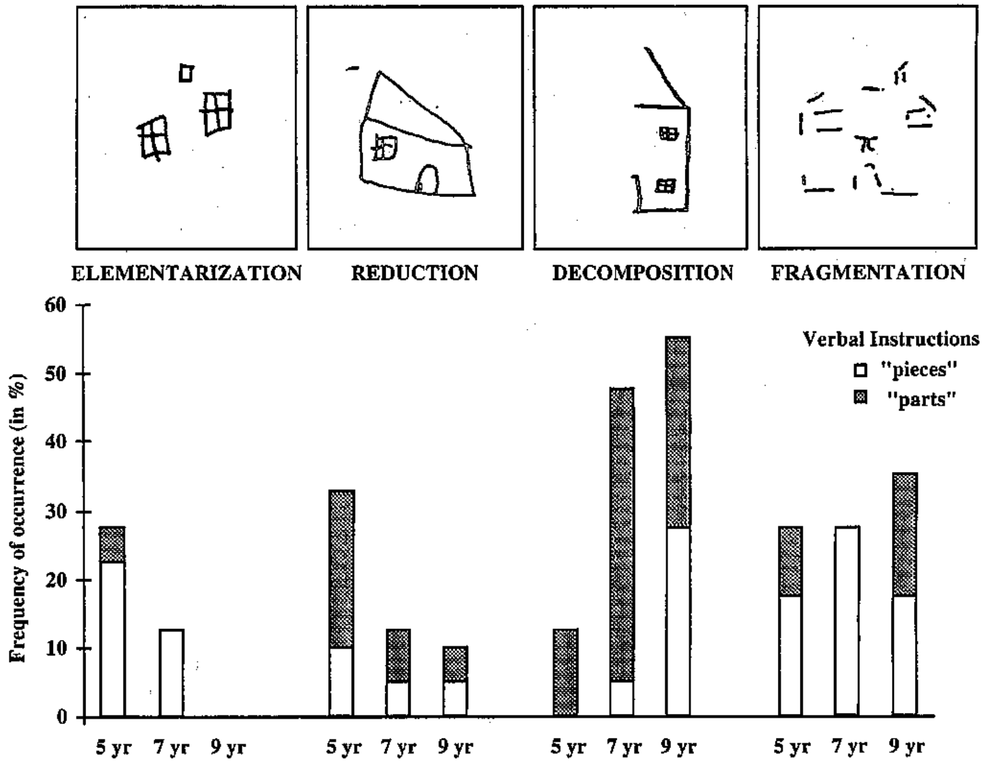

Figure 1. Mean frequency of occurrence (%) of each category of deletion produced in response to the 'pieces' and 'parts' verbal instructions as a function of age.

Figure 1 shows that the occurrence of the elementarized graphic representations clearly decreased with age ($F(2,54) = 4.31, p < .01$). Planned comparisons revealed that they were produced mainly by the youngest children, and tended to disappear from 7 years of age ($F(1,54) = 6.84, p < .01$). These elementarized drawings were induced mostly by the 'pieces' instruction ($F(1,54) = 6.82, p < .01$), to which they were indeed an appropriate response. The frequency of occurrence of reduced graphic representations also decreased with age ($F(2,54) = 2.95, p < .05$). Planned comparisons showed that these deletions were again mainly performed at 5 years and that they decreased strongly as of 7 years of age ($F(1,54) = 5.85, p < .01$). Deletions relating to the reduction category were elicited in equal measure by the 'pieces' and the 'parts' verbal instructions, no significant instruction effect being observed for this type of deletion ($p > .23$).

[3] Several studies have shown that ANOVAs can be used with binary data (see e.g. Hsu & Feld, 1969; Lunney, 1970).

The opposite developmental trend was observed for the decomposed graphic representations: they tended to become numerous with increasing age ($F(2,54) = 8.55, p < .01$). The increase of the tendency to split the graphic representations was most pronounced between 5 and 7 years ($F(1,54) = 10.17, p < .01$). The production of decomposed graphic representations was clearly induced by the parts instruction ($F(1,54) = 13.85, p < .01$), to which it provided an appropriate response. This was, however, not true at all ages, as indicated by a significant Age × Instruction interaction effect ($F(1,54) = 6.05, p < .01$). Planned comparisons revealed that 5- and 7-year-old children split the object into two parts only when they received the parts instruction, whereas the oldest children also adopted this behaviour in response to the pieces instruction ($F(1,54) = 6.92, p < .01$).

Interestingly, two different types of decompositions of the house were performed by the children: the object was split into two symmetrical and identical halves, only one of which was drawn (e.g. the left or the right half), or the object was decomposed into two non-identical parts which corresponded to its fundamental units (e.g. only the body or only the roof of the house was drawn, together with their respective elements). For the television, the decompositions were always of the first kind ('split-type'), presenting strong similarities with drawings performed by hemineglect patients. Whatever their age, children did not significantly produce more decomposed houses of the split-type than of the part-type ($F < 1$).

Finally, in contrast with the previous types of deletion, the fragmented representations did not differ in frequency as a function of age ($F < .1$). These fragmented drawings were induced mainly by the pieces instruction ($F(1,54) = 4.69, p < .05$). The bias for fragmentation in response to the pieces instruction was particularly obvious at 7 years, but less so at age 9. However, the Age × Instruction interaction effect did not reach a significant level ($F(2,54) = 2.32, p < .10$).

Procedural flexibility: A syntactical analysis of movement sequencing

We examined whether the children displayed a flexible or rigid sequencing of the movements involved in their drawing when moving from the Free-drawing to the Deletion task. This question was investigated using two types of indicators, one relating to the initiation of the drawing process, and the other to the interruption of the graphic sequences. As far as the initiation of the graphic sequences was concerned, three main parameters were analysed: the location of the first starting point, the direction of the first graphic movement, and the first graphic unit drawn. When switching from the Free-drawing to the Deletion task, children could adopt four different types of behaviour: (1) they could keep the three parameters unchanged (complete conservation); (2) they could start with the same graphic unit, but use a different starting point, and/or a different movement direction (unit conservation); (3) they could maintain the motor parameters constant (starting point and movement direction), but start with a different graphic unit (motor conservation); and (4) they could change the three parameters (no conservation). Children's performance was coded according to these criteria by two independent judges, and an overall agreement of 99.4% was obtained, the only source of divergence being due to mistakes in the reading of the sequencing reported for each drawing. The purpose of the second indicator was to analyse the moment in the course of their drawing activity at which the children interrupted their graphic routines to delete information in the depicted objects. Three different types of routine interruption were observed: (1) *at the beginning*—the deletion was performed while the child was drawing the first graphic unit; (2) *in the middle*—the child started as 'usual' (according to the baseline task), drew at least the first graphic unit, deleted some information and then finished as 'usual' (with reference to the baseline condition); and (3) *at the end*—the children drew at least the first unit as usual and once they had deleted some graphic features, did not draw any more. Note that this analysis did not take account of children who produced fragmented representations and piecemeal/elementarized representations because, in these cases, the question of the timing of the deletion was irrelevant. Thus, the analysis involved 11 children of 5 years of age, 13 children of 7 years, and 14 children of 9 years. Complete inter-judge agreement was obtained for the coding of children's performances according to these criteria. The results are displayed in Figure 2. A series of ANOVAs with Age (3) as a between-subjects factor and Object (2) as a within-subject factor was performed for both indicators.

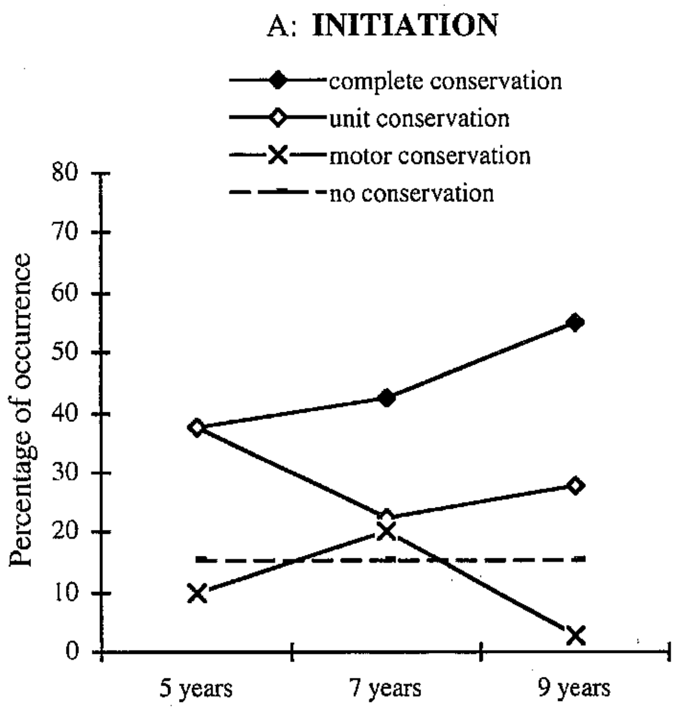

Figure 2A. Evolution with age of the mean percentage of occurrence of each type movement conservation for the initiation of the graphic routines in the Deletion task.

Figure 2A shows that the children had a strong tendency to initiate their drawing procedures as they did in the free-drawing task: the level of complete conservations of the initiation parameters was 37.5% at 5 as well as at 7 years, and reached 55% at age 9. This

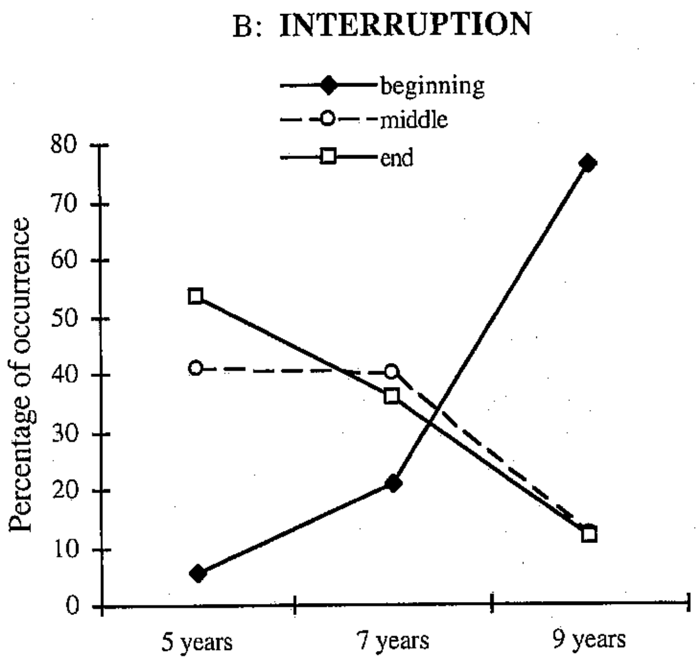

Figure 2B. Evolution with age of the mean percentage of occurrence of each type of interruption of the graphic routines displayed by children in the Deletion task.

increase was, however, not significant ($F < 1$). The percentage of unit conservations neither differed as a function of age ($F < 1$) and accounted on average for 29.2% of children's drawing behaviour. In contrast, the percentage of motor conservations varied significantly as a function of age ($F(2,57) = 3.21, p < .05$). *Post hoc* comparisons (Sheffé test) revealed that 9-year-old children did not present such motor conservations while the other children did ($F(1,57) = 4.33, p < .05$). Finally, a complete change of the initiation parameters was observed in 15% of the children's drawing behaviour, whatever their age ($F < 1$). Furthermore, the type of object had a significant effect on the frequency of unit conservation ($F(1,57) = 14.01, p < .01$); whatever the age, 16.6% of the sequences involved in the drawing of the house were initiated by the same unit as in the Free-drawing task, but with a different starting point and/or direction of movement, whereas this was observed in 41.6% of the cases for the television. The opposite result pattern was observed with regard to complete conservation, the frequency of which was higher for the house (53.3%) than for the television (36.6%) ($F(1,57) = 5.97, p < .01$). Both results suggest that the house led children to display a more rigid sequencing of movements than the television.

As far as the timing of the deletion is concerned, Figure 2B shows that age induced both an increase in the ability to interrupt the drawing sequences at their very beginning ($F(2,35) = 24.10, p < .01$) and a decrease in interruptions occurring in the middle ($F(2,35) = 4.32, p < .05$) or at the end ($F(2,35) = 4.97, p < .01$) of the sequences. Planned comparisons revealed that this developmental shift occurred mainly between 7 and 9 years, with all comparisons being significant at $p < .05$, whatever the type of interruption considered. Furthermore, significant object effects were obtained for the frequency of interruptions at the beginning ($F(1,35) = 15.03, p < .01$) and interruptions in the middle ($F(1,35) = 7.18, p < .01$). For the house drawing, the sequences were more frequently interrupted in the middle than at the very beginning (43.3% vs. 22.5%), the reverse being observed for the television (18.5% vs. 46.2%). These data once again emphasise the greater rigidity of the drawing sequences involved in the production of the house when compared with the television.

Finally, the associations were investigated between the types of representational changes introduced in the drawings and the children's ability to interrupt their drawing sequences. Regardless of age, the results showed that the production of reductions was significantly associated with interruptions of the drawing sequences at their very beginning ($\chi^2(4,38) = 14.14, p < .01$) and at their end ($\chi^2(4,38) = 18.24, p < .01$). Significant associations were also obtained between the production of decompositions and the interruptions of the drawing sequences at their early beginning ($\chi^2(4,38) = 16.32, p < .01$) and at their end ($\chi^2 4,38) = 14.18, p < .01$). Closer inspection of the data revealed that 83.3% of the full amount of reductions corresponded to drawings interrupted at the end of their run, whereas none of the reductions corresponded to routines interrupted at their early beginning. The reverse pattern of results was observed for the decompositions: 77.7% of the decomposed drawings were interrupted at their early beginning, and only 16.7% of them at the end of the routines.

Discussion

Flexibility at the representational level exhibited clear-cut age-related changes in the way that children responded to the deletion task: the youngest children produced mainly elementarized and reduced graphic representations, whereas the older children showed an increasing tendency to decompose the graphic representation into two parts. Another type of deletion, consisting of fragmenting the whole graphic representation, appeared with equal frequency across ages. These categories of deletion may be qualitatively distinguished as a function of the type of representational analysis they involved: producing elementarized and reduced graphic representations required an 'element-based' analysis of the representation, while producing decomposed graphic representations involved a 'part-whole-based' analysis of the representation. The fragmented graphic representations may be considered separately, because they did not require any semantic analysis of the object. They might result from changes affecting the executive level only: while drawing, the children introduced pen-lifts at more or less regular intervals, with the result that the depicted object finally appeared in crude dotted lines. Within this perspective, intra-representational flexibility in children's drawing behaviour evolved from 'element-based' changes (elementarizations, reductions) to 'part-whole-based' symbolic modifications (decompositions). This transition tended to occur at about age 7.

The sensitivity of this developmental sequence to contextual manipulation was tested by introducing the pieces and parts verbal instructions. The verbal instructions had a clear impact on the way the children deleted information; globally, the pieces instruction elicited both elementarized and fragmented graphic representations, and the parts instruction triggered decomposed graphic representations. The reduced graphic representations were elicited with equal frequency by both verbal instructions. However, the

9-year-old children produced decomposed graphic representations as often in response to the parts instruction as in response to the pieces instruction, while 5-year-old children tended to produce element-based deletions as often in the pieces context (elementarized representations) as in the parts context (reduced representations). These data show that, at ages 5 and 9, the children appeared largely insensitive to the parts and pieces contexts respectively. In contrast, the 7-year-old children displayed more flexible behaviour and took account of both verbal instructions. The results thus provide evidence for the existence of a sequential progression in the development of intra-representational flexibility in children.

Flexibility at the procedural level was already present in 5-year-old children, who interrupted the drawing sequences in the middle in 40% of the cases, but increased strongly between 5 and 9 years, as indicated by a shift from deletions performed at the end or in the middle of the graphic sequences to deletion of information at the beginning of the sequences. As expected, a greater rigidity characterized the graphic routines for the house when compared to those used for the television, but no difference was obtained with regard to the types of deletions made to the two objects.

A comparison of the results obtained at the representational and procedural levels suggests that when the drawing sequences were completely freed from their sequential constraint they were accompanied by the production of elaborate representational changes. Indeed, we may well ask what effect the procedural constraints of drawing have on children's ability to produce representational changes in their drawings.

The second experiment was designed to investigate this question. It was necessary to identify a deletion procedure that keeps the requirements of representational flexibility constant, but suppresses the constraints linked to the motor aspects of drawing. In Expt 2, the children were asked to delete pieces or parts of pre-printed 2D line drawings using an eraser.

If the procedural constraints of drawing do not prevent the expression of representational flexibility, deletions performed with the eraser should reveal types of end-products and types of developmental trends similar to those found in Expt 1. Differences may be expected, however, in terms of the quantity of deletion involved in each type. Fewer fragmented drawings should be observed because this category of deletion appears to be more specific to drawing, the deletions being performed in the course of the execution of the drawing sequence. In contrast, the occurrence of the reduced graphic representations should increase, because children start from existing drawings and a natural use of the eraser could simply result in a reduction of the pre-printed drawings.

EXPERIMENT 2

Method

Participants

Sixty children, without any graphic or academic problems, participated in the experiment. They were divided into three age groups of 20 subjects each: 5 years (mean age = 5.06; 12 girls and 8 boys); 7 years (mean age = 7.23; 10 girls and 10 boys); and 9 years (mean age = 8.98; 12 girls and 8 boys). The same selection criteria as those used in Expt 1 applied for Expt 2. None of these children had participated in Expt 1.

Material

Two pre-printed 2D line drawings of a house and a television, illustrated in Figure 3, and an eraser were used in the experiment. Each drawing was easily identified by the children, and presented a featured version of the objects. The 2D line drawing of the house comprised 12 units, including two basic units (the body and the roof), eight internal units (two windows with panes and shutters, one door with a lock), and two external units (a chimney and an aerial). The 2D line drawing of the television comprised nine units: one basic unit (the body), five internal units (a screen, a switch panel with three knobs inside), and three external units (an aerial and two feet as a support).

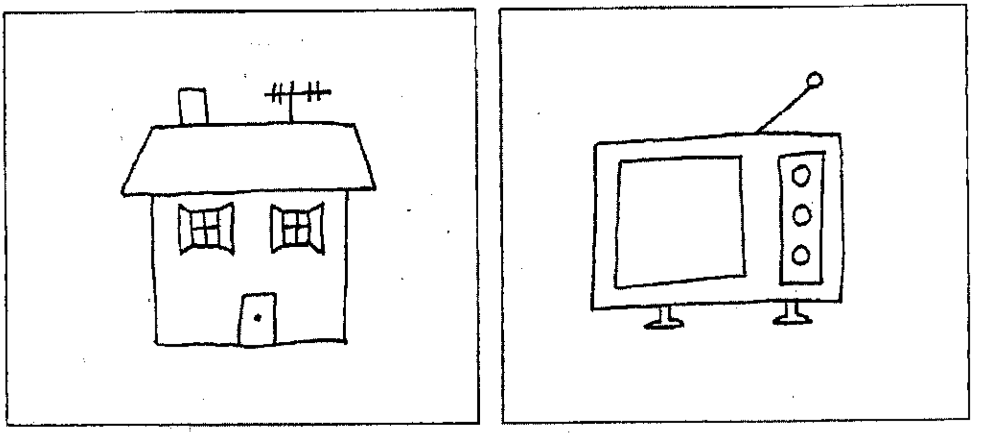

Figure 3. Illustrations of the pre-printed 2D line drawings used in Expt 2.

Procedure

The 2D line drawings of the house and the television were presented successively to the children. After the children had named a first object, the experimenter explained that a magician had tried to render it invisible with the help of his magic powers. Unfortunately, the magician could not remember his magic formula properly, and the object was finally only partially invisible. The children were required to erase some features of the object in accordance with one of the following verbal instructions: 'We can only see a few bits of the object' (pieces instruction), or 'We can't see all of the object any more' (parts instruction). Half of the children of each age group had to delete a certain amount of graphic information on hearing the pieces verbal instruction, and the other half in response to the parts verbal instruction. Before using the eraser, the children were asked to tell or to show with their finger what they wanted to erase on the 2D line drawings. This precaution was taken to avoid a ballistic use of the eraser on the pre-printed drawings. The order in which the 2D line drawings were presented was counterbalanced within each age group. No comment on the choices of deletions was made during the experiment, which was taken individually and lasted on average 10 min. While the children were performing the deletions, a second experimenter noted the features they were suppressing and the order in which the elements were erased. Again, the experimental sessions were videotaped and the recordings were used offline to check and correct the online coding if necessary. This was necessary in 1% of the cases.

Results

Deletions performed with an eraser fit into the four categories of deletions defined in Expt 1. The coding of children's behaviour as a function of these categories was performed by two independent judges, and the percentage of agreement was 97.5%. Figure 4 shows the evolution with age of the frequency of each type of deletion produced in response to the pieces and parts verbal instructions. Illustrations of the erased drawings are located in the top part of Figure 4 for each type of deletion. Their strong similarity to the deleted drawings obtained in Expt 1 can be noted. Planned comparisons were carried out on age for each type of deletion to test the hypothesis that developmental effects similar to those found in Expt 1 were obtained with the eraser procedure. Furthermore, ANOVAs were carried out with Age (3), Experiment (2) and Verbal Instructions (2) as between-subjects factors, and Object (2) as a within-subject factor, to test potential differences between the two experiments.

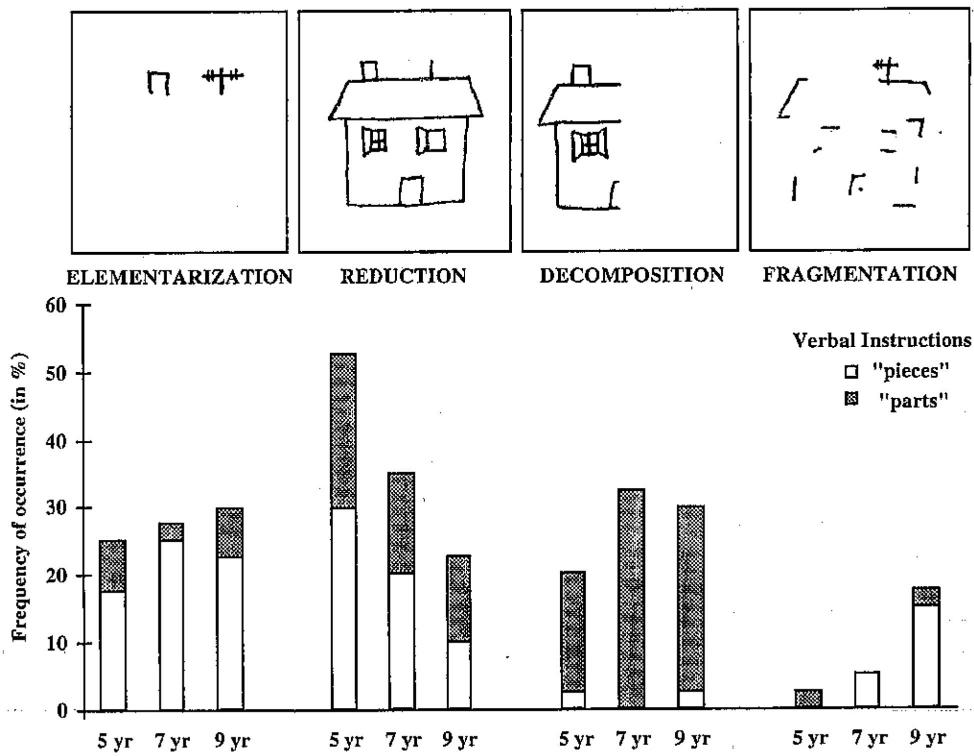

Figure 4. Mean frequency of occurrence (%) of each category of deletion produced in response to the 'pieces' and 'parts' verbal instructions as a function of age.

Planned comparisons revealed that the frequency of occurrence of the elementarized graphic representations did not decrease from 5 to 7 years of age as they did in Expt 1 ($F < 1$), but the frequency of reduced graphic representations did ($F(1,54) = 3.74, p < .05$). The verbal instructions had an impact on these types of deletion similar to that reported in Expt 1: elementarizations were elicited mainly by the pieces instructions ($F(1,54) = 10.12, p < .01$), and reductions by both verbal instructions ($F < 1$). The frequency of occurrence of decomposed graphic representations was lower at 5 years than at 7 or 9 years, but this increasing trend was not significant ($p > .23$). Whatever the age, this category of deletion was clearly induced by the parts instruction ($F(1,54) = 30.39$, $p < .01$). For the house condition, a significant Age × Type of decomposition ('split-type' vs. 'part-type') revealed that, from 7 years, the children essentially produced split-type decompositions, while the youngest children produced both types of decompositions ($F(1,57) = 4.24, p < .05$). Finally, the fragmented graphic representations did not differ significantly as a function of age ($F(2,54) = 2.02, p > .14$), although Figure 4 shows that they tended to be more numerous at 9 years. As in Expt 1, the object introduced no significant effect on the occurrence of the types of deletion (p ranging from .16 to 1.0).

ANOVAs revealed that the frequency of occurrence of the element-based deletions (elementarizations and reductions) was higher in Expt 2 than in Expt 1 ($F(1,108) = 5.09$, $p < .05$; $F(1,108) = 6.64$, $p < .01$, respectively). In contrast, the fragmented representations were less numerous in Expt 2 than in Expt 1 ($F(1,108) = 11.83$, $p < .01$). The 'part-whole-based' deletions were also less numerous, but the effect was only marginally significant (decompositions, $F(1,108) = 2.98$, $p < .08$). *Post hoc* comparisons (LSD test) revealed that the frequency of occurrence of elementarization differed significantly at age 9 ($p < .01$), being higher in Expt 2 than in Expt 1, but not at age 7 or age 5 ($p > .17$ and $p > .81$, respectively). Similarly, *post hoc* comparisons showed that the frequency of occurrence of decompositions differed significantly at age 9 ($p < .05$), being lower in Expt 2 than in Expt 1, but not at age 7 or age 5 ($p > .16$ and $p > .49$, respectively).

Discussion

When compared to the deletion procedure used in Expt 1, the erasing procedure elicited similar types of representational changes, but introduced differences both in terms of their frequency and developmental trends.

Deletions performed with the eraser result in fewer fragmentations, and more reductions of the 2D line drawings. As hypothesized, the fragmented drawings were specifically induced by changes introduced during the course of the graphic routines, without necessiting a conceptual analysis of the graphic representations. Avoiding the necessity to run graphic routines therefore strongly diminished the frequency of occurrence of this category of deletion. With regard to the reduced graphic representations, it could be suggested that the children performed a perceptual analysis of the 2D line drawings that led them to focus on the salient elementary components of the objects. In other words, the task itself may elicit an analytical perception of the pre-printed drawings in children. Reductions were more numerous at all ages in Expt 2, but, as in Expt 1, their frequency of occurrence decreased strongly between 5 and 7 years, confirming that young children were more inclined to work on elements than older children.

Regarding developmental trends, the differences between the experiments concerned the production of elementarized and decomposed representations. These categories remained constant in frequency across ages in Expt 2, whereas in Expt 1 age 7 witnessed a decline in elementarized drawings coupled with the emergence of decomposed graphic representations. However, a closer comparison of the two experiments revealed that, in Expt 2, 5-year-old children produced as many elementarizations and decompositions as in Expt 1, while 7- and 9-year-old children produced fewer decompositions and more elementarizations than they did in Expt 1. The idea that procedural constraints prevent the expression of representational changes cannot explain the present data. If this were the case, the erasing procedure should have increased the production of decomposed graphic representations in the youngest children; indeed, decompositions required a greater syntactical flexibility than elementarizations or reductions, which simply involved the extraction (elementarization) or omission (reduction) of subunits in the graphic routines. The changes observed at ages 7 and 9, relating to both the greater production of elementarizations and the reduced production of decompositions, can also not be accounted for by procedural constraints on representational changes.

GENERAL DISCUSSION

Both experiments provided congruent and complementary information about intra-representational flexibility in children's drawing behaviour and its relationship to procedural flexibility.

Expt 1 revealed that, if flexibility at the conceptual or symbolic level is present in young children as well as in older children, it changes qualitatively between 5 and 9 years of age. The production of mainly 'element-based' deletions characterized the youngest children, while the production of 'part-whole-based' deletions was mostly observed in the oldest children's behaviour. The performance of the 7-year-old children exhibited both a decline in the element-based deletions when compared with the youngest children, and the emergence of part-whole-based deletions when compared with the oldest children. These results confirm the age-related intra-representational changes made by children in response to the requirements of an innovation task (Vinter & Picard, 1996). In our view, these changes reflect an increase in the size of the internal cognitive unit which becomes flexible in the course of development. A similar conclusion was drawn from a study in which the impact of the meaning attributed to pre-printed drawings on syntactical copying strategies was analysed between 6 and 10 years of age (Vinter, 1999). Furthermore, the low level of sensitivity to the pieces and parts verbal instructions at ages 9 and 5, respectively, provide evidence for a sequential progression in performing representational changes.

Rigidity at the procedural level was shown to be present in the young children's drawing sequences (Expt 1), but data added by Expt 2 suggested that the procedural constraints of drawing do not prevent intra-representational flexibility from being expressed in children's drawings.

In Expt 2, the developmental sequence observed in Expt 1 was only partially replicated. In the children aged 7 and over, a decrease was observed of the occurrence of the reduced graphic representations for the element-based changes. In contrast, the part-whole-based changes (decompositions) and the elementarizations appeared with equal frequency across ages. However, the elementarizations may have a somewhat ambigous status. When the child directly draws pieces or elementary components of the object (Expt 1), a simple element-based analysis of the underlying graphic representation is required. In contrast, when elementarized graphic representations result from the erasing procedure (Expt 2), children have to focus on elementary components of the object, namely those they want to remain visible, but cannot work on them directly. Because the other elements have to be deleted first, an analysis of the relationships between the remaining visible elements and the other parts of the graphic representation is required.

Two different interpretations may account for these results. First, it is possible that behaviours with a surface similarity are underpinned by similar strategies in children. If this interpretation is correct, the developmental sequence demonstrated by Expt 1 may be only apparent and contextual, with young children being able to perform part-whole-based representational changes as well as older children.

Secondly, behaviours with a surface similarity may reflect different strategies in children. Such a view is defended by Karmiloff-Smith (1992). We would argue in favour of this second hypothesis, because a variety of findings tend to indicate a high conservative behaviour in the youngest children only. For these young children, similar amounts of decompositions and elementarizations were obtained in both experiments, and similar amounts of split-type and part-type decomposed houses were observed in both experiments. In contrast, the older children produced more elementarizations and fewer decompositions in Expt 2 than in Expt 1, and more split-type decomposed houses in Expt 2 than they did in Expt 1. We may therefore suggest that a rigid behaviour in 5-year-old children was characterized by their strong tendency to work on the elements rather than on the whole representation, whatever the deletion procedure. In the older children, the greater production of elementarization in Expt 2 than in Expt 1 might be related to the fact that this type of deletion may be part-whole-based because of the specificity of the erasing procedure. The reduced production of decompositions obtained at 9 years may also be related to the particular status of this type of deletion in Expt 2. Indeed, split-type decompositions were almost exclusively produced at this age, that is to say decompositions which could be essentially perceptually driven. Whereas decompositions of the split-type may be mainly perceptually driven, because participants neglect one half of the whole object along a symmetrical axis, those of the part-type can be expected on the basis of a categorical decomposition of the object, because the remaining visible part exists on its own. In conclusion, the changes observed in the older children were mainly contextual in our view, the erasing procedure eliciting both the production of piecemeal graphic representations through a part-whole-based analysis of the representations, and the preferential production of split graphic representations, through a perceptuo-motor analysis of the pre-printed drawings. Thus, despite some differences in the developmental trends, the data collected in Expt 2 remained compatible with the age-related sequence reported in Expt 1.

As previously stressed, children's ability to generate representational changes may be accounted for by changes in the size of the internal cognitive unit with which they plan their behaviour. In this perspective, evolving flexibility in children's drawing behaviour may be related to qualitative changes in the internal representations, in particular to the shift from partial to whole representations (Minary & Vinter, 1996; Mounoud, 1992; Vinter, 1999). However, changes can also be underpinned by more quantitative modifications relating, for instance, to an extension in the size of the working memory. It has been shown that sequential changes in children's drawings performance could be characterized in terms of Case's (1985, 1991) four-stage developmental model (Bensur & Eliot, 1993). Within this perspective, developmental changes in children's drawing behaviour may be linked to general stages of their cognitive growth and shed light on general changes in intellectual development.

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