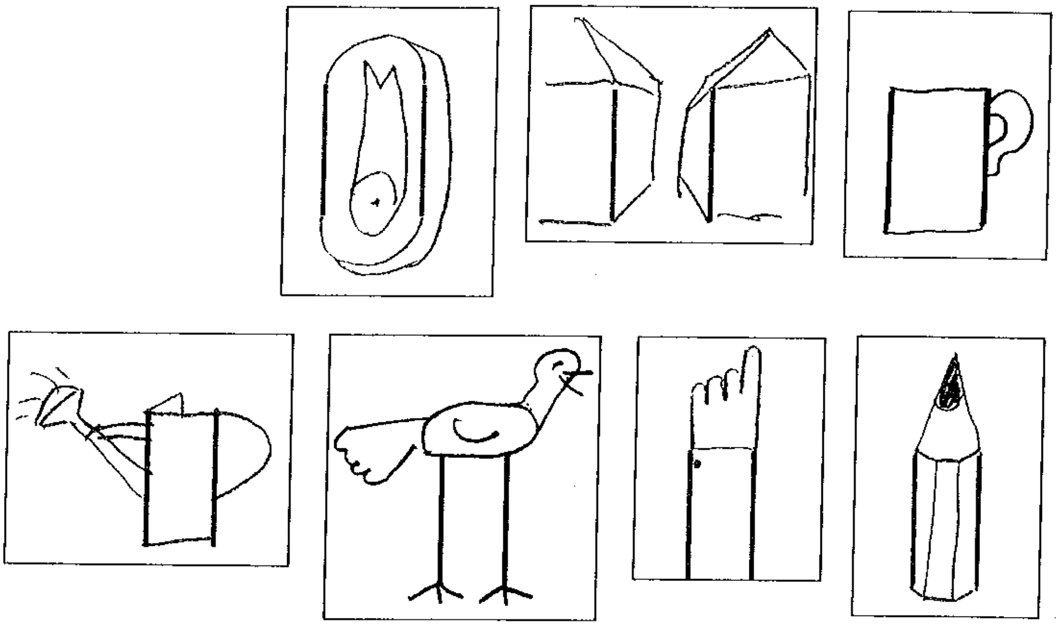
Drawing and the Non-Verbal Mind

A Life-Span Perspective



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8 Graphic syntax and representational development

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This chapter focuses specifically on the relationships between syntax and cognitive development, particularly representational development. Vinter, Picard and Fernandes promote the take-home message that changes in drawing behaviour during development result from changes in the size of the cognitive units or mental representations used to plan behaviour, and in the capacity to manage part–whole relationships. This hypothesis is first illustrated by reviewing studies in which children's adherence to the graphic rules when they copy elementary or complex figures is assessed. The authors also examine children's syntactical behaviour at a more global level, characterizing the entire drawing sequences built by children when they produce a drawing. Children's graphic strategies appear to reflect how they conceive of the patterns they reproduce. Task constraints (meaning given to the pattern, type of primes used to enhance specific strategies) contribute to modify their syntactical behaviour, but not uniformly throughout development. A three-step developmental model outlined in the first section of the chapter finds further support in studies dealing with procedural and representational flexibility. Finally, the authors report an original perspective on studying syntactical drawing behaviour, where it is shown that this behaviour can be incidentally modified through directed practice in children as well as in adults. By the way, the results reported by Vinter, Picard and Fernandes reveal the extent to which syntax constitutes a flexible component of drawing behaviour.

DRAWING BEHAVIOUR has been studied from many different points of view and used to assess many different aspects of psychological functioning (i.e. perceptual, motor, cognitive, emotional). Among these approaches, one distinguished between the 'syntax' and the 'semantics' of drawing (Van Sommers, 1984). Syntax in drawing refers to the way the movements are executed and ordered in a sequence (the 'how' of drawing), while semantics deals with what is depicted in terms of symbolic content (the 'what' of drawing). The present chapter will focus on drawing syntax, attempting to demonstrate that the way children organize their drawing activity locally (applying graphic rules) and globally (using graphic strategies and routines) provides relevant indicators of the nature of their mental representations, and particularly of the size and degree of flexibility of their cognitive units. It shows that drawing behaviour provides a rich and sensitive non-verbal indicator of mental representations, and particularly of conceptual knowledge. Nice empirical demonstrations of the relationships between drawing and conceptual knowledge can also be found in studies of drawings produced by patients with semantic dementia (e.g. Bozeat, Lambon Ralph, Graham, Patterson, Wilkin, Rowland, Rogers and Hodges, 2003).

The chapter is composed of four sections. A first short section deals with the *local* level of syntactical organization of drawing, studying how children at different ages apply graphic rules in the drawing of simple or complex models, and how contextual factors may modify these processes. The second section deals with the *global* level of syntactical organization of drawing, and encompasses equally a developmental approach together with the study of contextual effects. Then, in a third section, the way both levels coordinate and interact will be studied focusing on the relationships between procedural and representational flexibility in drawing. A sketch for a developmental representational model that can account for syntactical drawing behaviour will be briefly outlined. Finally, in a fourth section, a different viewpoint on syntactical graphic behaviour will be adopted, showing how it can be modelled by experience.

This chapter aims at promoting the idea that most developmental changes in drawing behaviour result from changes in the size of the cognitive units or mental representations used to plan behaviour (reduced to elements first, extended to chunks of elements, then enabling a capacity to process whole entities), and in the capacity to manage part–whole relationships (whole mental representations are first not decomposable, then become progressively decomposable; see Vinter and Marot, 2007). This position is different but complementary to the one expounded in another chapter (see Morra, this volume), which sustains that the main determinants of drawing performances relate to executive functions. Empirical evidence will be progressively accumulated through the next three sections to provide support to a three-steps developmental model that will be introduced later on.

The local level of syntactical organization of children's drawing movements

Goodnow and Levine (1973) defined a 'grammar of action' to account for the executive constraints acting on drawing (see also Simner, 1981;

Van Sommers, 1984). The production of the segments in a drawing is governed by a set of graphic rules which specify where to start (top, left) and how to progress in the drawing (top-to-bottom, left-to-right, threading, i.e. drawing continuously without pen lifts). How children adhere to these rules in the course of development has been examined in different studies (see Goodnow and Levine, 1973; Nihei, 1983; Ninio and Lieblich, 1976), but none of them has included a large range of ages and investigated systematically the sensitivity of rules to geometrical factors. Our own work was guided by the idea that the observance of the rules by children should reveal whether graphomotor activity was planned mainly at the segment or figure level.

In a first study, we asked children aged 4 to 9 years and adults to copy simple models made of two connected segments (L-shapes) of different lengths and presented in different orientations (Vinter, 1994). Between 4 and 5 years, children had a clear preference to start at left and to progress left-to-right, whereas they oscillated between starting at top or at bottom, and progressing top-to-bottom or bottom-to-top, especially at segment level. A transition appeared between 5 and 6 years, with the establishment of a strong dominance of a top start and of threading. Planning the copy occurred at the figure level from this moment, leading to recurrent violations of the left-start rule, or of the left-to-right progression rule. A second transition took place between 8 and 9 years, the 9-year-olds showing syntactical behaviour similar to that of adults in the present task: dominance of threading diminished while the top-to-bottom and left-to-right progression rules gained in importance. A better equilibrium appeared between an economical copy of the figure (minimizing the pen lifts) and a comfortable tracing (observance of the progression rules for the vertical and horizontal segments). We have suggested that this behaviour revealed a capacity to coordinate and integrate planning at figure and segment levels. A similar development was reported in a study where children and adults had to copy multisegmental patterns made of horizontals and verticals (Marot and Vinter, 2003).

To what extent would this local syntactical behaviour be modified when familiar objects instead of geometrical patterns were required to be depicted in different drawing tasks? Effects of context are plentiful in the drawing research domain. A large body of research has shown that modifying the familiarity or complexity of the model to be depicted, the verbal instructions or the episodic information provided to children before they draw elicits a high level of variability (e.g. Barrett, Beaumont and Jennett, 1985; Cox, 1992; Davies, 1983; Nicholls and Kennedy, 1992; Picard and Durand, 2005; Sutton and Rose, 1998). In a second study, children aged 5, 7 or 9 years had to copy, or draw from memory, a familiar object like a house or a television (Picard and Vinter, 2005).

Several points are worth mentioning from this study. Application of the graphic rules was modulated by geometrical factors, especially the size of the drawn segments (*younger* children had a tendency to start drawing the longest segment) and the size of the drawn component of the figure (*older* children used threading only for the smallest components of the depicted figure, like the windows of the house). We again found here a distinction between planning at the segment level (typical from young children) or at the figure level (characteristic from older children). Furthermore, the observance of the starting rules was determined by a syntactical rule of higher order, in the sense that it structured the sequence of drawing movements, more precisely the linkages of components. In the house drawing, the *accretion principle* (starting a new segment by anchoring it in an already drawn segment, see Van Sommers, 1984, p. 41) organized the linkage between the drawing of the body and of the roof of the house, implying a violation of the top-start rule for the drawing of the roof. The same sequence occurred with the drawing of the door. In consequence, the observance of the top-start rule was much less stable than that of the left-start rule, showing that the hierarchy described in our first experiment may be partially a function of the figures depicted. Finally, there was, at an individual level, a rather strong conservatism between the copy and the drawing from memory task in the application of the graphic rules when components of the figures (e.g. the door, the roof, etc.) were considered. This conservatism is at the origin of the graphic routines established for the drawing of familiar objects. However, the copying task tended to cause a slightly less organized behaviour than the drawing from memory task, except children at 5 years who applied threading quite rigidly in both tasks.

The above reported set of studies showed that as soon as the depicted models attain a certain degree of complexity, a compromise must be found between the application of the local graphic rules and the more global strategies of drawing. This higher level of syntactical planning has also been the object of numerous studies and constitutes another entry into the development of mental representations in children.

The global level of syntactical organization of children's drawing movements

How do children proceed in building a drawing? To what extent do they proceed following codified and stable sequences of movements (or 'formulas', or 'strategies') that may give rise to graphic routines in the case of drawing familiar objects (Picard and Vinter, 2005; Stiles, 1995; Van Sommers, 1984)? Van Sommers demonstrated that both geometrical (spatial) and semantic forces act on the way children or adults organize

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their global sequences of drawing movements, and he subsumed these constraints under three main principles: the *accretion principle* (defined as the tendency to anchor new units on already-drawn ones), the *core-to-periphery progression principle* (which dictates to draw the core or essential units prior to the peripheral or contingent ones) and the *subsystem elaboration principle* (which stipulates that geometrically or semantically linked units are drawn in sequence). Picard and Vinter (2005) have shown that the more semantically based principle, i.e. the core-to-periphery progression principle, predominated when children drew in a drawing from memory task, while the subsystem elaboration principle prevails in a copying task. This suggests that the nature of the drawing task, drawing from memory or copying, contributes to determine whether syntax is driven more by semantics or by geometry, at least in the drawing of familiar objects.

Could semantics directly drive syntax or does it necessarily compete with geometrical constraints (see also Tallandini and Morassi, this volume)? Ingram (1985) revealed that the semantic content of objects affects the way they are drawn by children. In a first experiment, children had to reproduce two plain-faced but different-sized blocks joined by a bridging pin under different spatial arrangements; in a second experiment, doll-like features were added to the smaller of the two blocks. The doll-like object induced the 3-year-old children to draw their tadpole stereotypes, whereas the more abstract object led them to rely on spatial information and to draw more advanced features. However, how much semantics intrudes in syntax cannot be assessed adequately in the experiment because the display to be drawn actually changed from one condition to the other (due to the doll-like features' adjunction), introducing modification at the syntactic level independently of meaning. This question has been elegantly tackled by Van Sommers (1984), who asked adults to reproduce models that were given one of two different labels (for instance, the same display was presented as a pyramid and its reflection in water or as a diamond crossed by a line). He found that, for most designs, adults modified their drawing movement sequencing as a function of the model's meaning. Note that this sensitivity of lower levels of behavioural organization to higher-level semantic influences has also been described with regard to actions other than drawing. Marteniuk, McKenzie, Jeannerod, Athenes and Dugas (1987), for instance, analysed the kinematics of an identical reaching movement when this movement was followed by one of two different actions, either fitting or throwing. They reported that the final goal of the overall sequence of action, its 'meaning', influenced the kinematics of the initial reaching movement.

We investigated the sensitivity of syntax to meaning in children using Van Sommer's procedure (Vinter, 1999), in which different displays were each attributed two different meanings, suggesting different parsings of the model, e.g. a single object could be either one representational unit (e.g. a diamond), or two representational units (a pyramid and its reflection), or different segmentations of two representational units (e.g. a glass with a cherry versus a man with a telescope), or still more subtle, a change of point of view (the letter N versus the letter Z rotated). Children aged between 6 and 10 years and adults participated in the study. An impact of meaning on syntax was reported from 6 years of age on for some displays, and it increased with age. The results suggested that as long as geometry and executive constraints on the one hand, semantic forces on the other, were acting in the same direction, the drawing behaviour of the youngest children was open to semantic influences. However, if a conflict arose (for instance, between the threading constraint, so strong at 6 years, and the necessity to lift the pen for marking a segmentation between two representational units), geometry and executive constraints took priority on semantic affordances in the youngest children. It was only when children were able to introduce flexibility at the lower syntactical level (9–10 years) that their drawing behaviour reflected more or less systematically the parsing dictated by semantics.

In this experiment, meaning was proposed by the experimenter in order to elicit different parsings of the model. We now wonder how graphic syntax would evolve with age when children have to copy models that present both a global and local structure, thus potentially eliciting different meanings (for instance, a square divided into four small squares, or a square and a sign '+' inside, or four small squares joined together). Stiles and her colleagues (e.g. Akshoomoff and Stiles, 1995a, 1995b; Dukette and Stiles, 1996) showed that, when asked to copy such spatial patterns, young children were capable of attending to both local and global information, but they tended to parse out simpler and more independent parts, and to use simpler relations than older children. Using a Navon Figure copying task (Navon, 1977), Lange-Küttner (2000) revealed that global processing largely dominated at 5 years, while an integration of local and global information was apparent at 11 years. We found again in Van Sommers' work a source of inspiration to tackle this question. Indeed, in one of his experiments, he asked adults to copy a pattern made of rectangles arranged in the form of ascending or descending stairs (see Figure 8.1A), and reported the main graphic strategies they employed in this task. Some of these strategies involved building the drawing region by region, starting with the largest rectangle and attaching smaller three-sided rectangles, or with the smallest and embedding one side of each into a larger rectangle

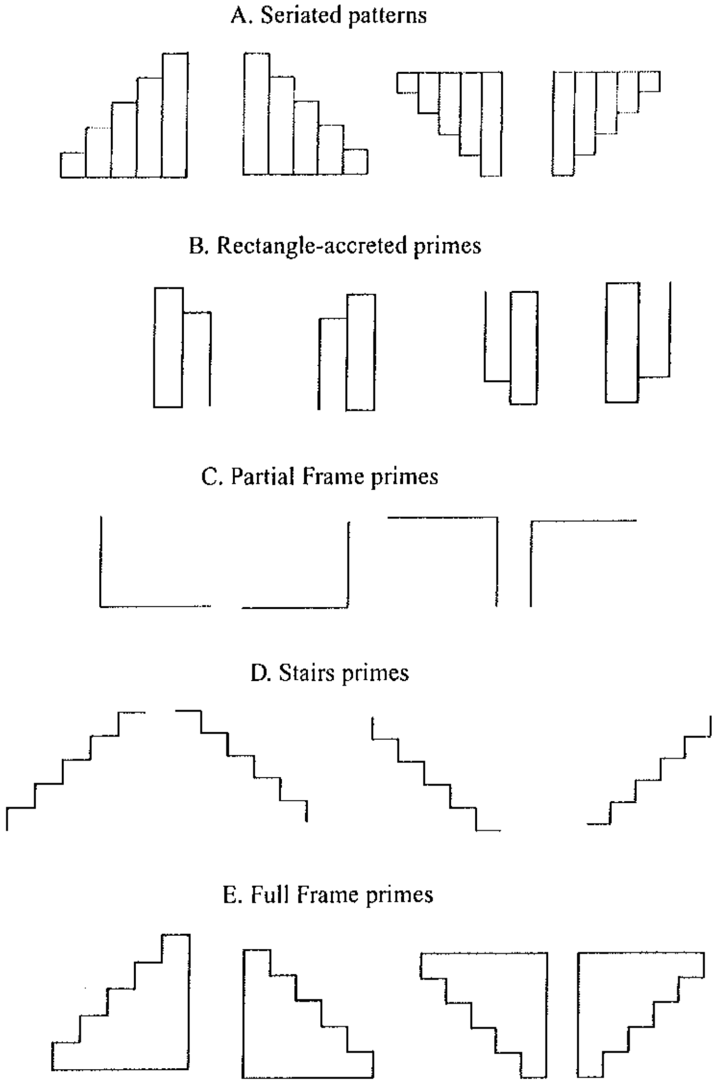

Figure 8.1 Illustration of the seriated models and the primes used in the experiments.

(see Vinter and Marot, 2007, for illustrations). In two other strategies, the pattern was processed partly or wholly as a single unit enclosed in a frame, with the shared boundaries represented as added internal segments. We thought that the first type of strategy could reflect an understanding of the pattern as composed of N rectangles (local structure) that were assembled and seriated, while the second type of strategy could involve a conscious focus on the entire configuration (global structure), which was then decomposed into parts. If this analysis were correct, asking children to copy these seriated patterns would be most interesting because systematic modifications of strategies as a function of age could be expected in relation to their increasing capacity to parse information integrating both local and global dimensions (Carey and Diamond, 1977; Kemler Nelson, 1984, 1989; Tada and Stiles, 1996).

Children aged 5 to 10 years and adults participated in the study (Vinter and Marot, 2007). They were requested to copy the seriated patterns, with an increasing or decreasing structure, and in different orientations. We made a complete inventory of the strategies used by the participants in the task, and noted that some of them were typical for young children. Indeed, 5-year-old children copied the figures as a series of individual, independent rectangles, in a more or less loose length seriation, with sometimes some attempts to juxtapose the rectangles. We construed these strategies as *element-based*, involving a conceptualization of the pattern as a series of rectangles, due to a strong dominance of local information processing, and resulting in a conceptualization of the pictorial space as an *aggregate space* (Lange-Küttner, 1997, 2004). This step was very similar to the one described previously, where young children plan their activity at a *segment level*. Between 6 and 10 years, children correctly depicted the patterns as unique or whole figures made up of a series of rectangles sharing one side, and the drawing was constructed by taking the rectangle located at the extremity of the series as a unit block, accreting the next to it, or embedding the next in it. We construed these strategies as *unit-based*, where the pattern was conceived of as a whole pattern resulting from an assembly of connected rectangles. This step showed that children were capable of planning at the *figure level*. Finally, a third step emerged at 10 years and was characteristic of adults, who used *part–whole-based* strategies, where the frame of the pattern was drawn first, totally or partially, and then complementary segments were added so that the rectangles emerged. These strategies requested the management of part–whole relationships so that the global representation of the pattern could be decomposed into a frame and parts combined in a coordinated structure. We consider that such capacity to process part–whole relationships sustains the ability to plan activity at an integrated figure and segment level.

Would this developmental sequence resist contextual effects such as those involved by a manipulation of the individual's prior experience (see, for instance, Bremner and Moore, 1984; Lewis, Russell and Berridge, 1993; Phillips, Inall and Lauder, 1985)? Outside of the drawing research domain, Schyns and Rodet (1997) have demonstrated that the immediate appearance of patterns, that is, the way a pattern is parsed, can be modified by prior experience. Thus, in four priming experiments, we tested whether children and adults who were exposed to specific parses of the seriated patterns would be subsequently inclined to resort to graphic strategies directly suggested by the primes, when they are asked to copy the entire patterns. Children aged 5, 6, 8 and 10 years and adults participated in four priming conditions (Vinter and Marot, 2007). In the first one, the participants were required to copy a rectangle to which an open rectangle was attached, in several orientations, before the copy of the seriated patterns (see Figure 8.1B). This prime corresponded to the beginning of a *unit-based* strategy and was thus expected to enhance such strategies. In a second condition, the partial frame of the seriated pattern was used as a prime (Figure 8.1C), the stairs part was presented as a prime in a third condition (Figure 8.1D), and the complete frame in a fourth condition (Figure 8.1E). These three last primes should enhance the production of part–whole-based strategies. The priming procedure had a great impact in the 5-year-olds, who tended to abandon the element-based strategies to the benefit of the part–whole-based ones in all experiments but the one where the full frame was used as a prime. They also displayed a typical behaviour, starting the drawing of the seriated pattern by the prime component, some of them continuing with a part–whole-based strategy, others continuing with element-based strategies, thus producing typical prime-induced errors in which the prime component and the individual rectangles co-existed. The 6-year-old children and adults were reluctant to modify their strategies after priming. They produced the same strategies after priming as those in the baseline condition. Finally, the 8- and 10-year-old children were positively influenced by the primes that were expected to increase the production of part–whole-based strategies.

Because the management of part–whole relationships is progressively appearing between 8 and 11 years (e.g. Akshoomoff and Stiles, 1995a, 1995b; Piaget and Inhelder, 1956; Picard and Vinter, 1999), we can easily conceive that the priming phase acted as an external aid that triggered the production of part–whole-based strategies in the 8- and 10-year-olds. The manipulation of the children's personal experience of the patterns helped them to build a new representation of their structure, that, in turn, guided their drawing strategies. That adults constantly produced the part–whole-based strategies, even in a context inducing unit-based strategies, demonstrates that they had stabilized their drawing behaviour around the most powerful and economical solution. Indeed, the part–whole-based strategies are the best adapted to the structural features of the models, allowing for a perfect base alignment of the rectangles, for an optimum use of drawing in preferred directions, and with a minimum number of pen lifts. Accounting for the performance shown by the 5- and 6-year-olds in the priming conditions is less obvious. However, the Karmiloff-Smith (1992) model enables explanations of this performance. In this model, a first phase of development results from accumulated practice in a domain, thanks to highly efficient data-driven processing. This very same efficient data-driven processing would be responsible for the impact of the priming phase at this age. Would this mean that these young children were able to display sophisticated representational abilities (part–whole analysis) upon external triggers? Endorsing the view that apparently identical behaviour can be sustained by qualitatively different representational structures (Karmiloff-Smith, 1999), we suggested that it was not likely (Vinter and Marot, 2007). Recalling that these young children tended to initiate their copy of the seriated patterns by drawing the prime component first, an appropriate use of data-driven processes led some to establish a segment-by-segment correspondence between their drawing and the model. Thus, a part–whole-based strategy emerged, created or assembled anew during the drawing process, independently of any internal reworking of how the patterns were conceived. The exogeneous trigger caused the 5-year-olds not to rely on element-based strategies, but to display apparently more sophisticated drawing behaviour. By contrast, the 6-year-olds did not. This testified to a certain closure of their cognitive system to external inductions, as would be predicted by the Karmiloff-Smith model with its notion of representational redescription (1992), or from a certain degree of conceptual rigidity as postulated by Mounoud (1988, 1996) at this age.

We saw, on several occasions, that the local and global levels of organization in drawing interact in producing the individual's final behaviour. These interactions between a lower executive level, more dependent on biomechanical and geometrical constraints, and a higher planning level, more dependent on representational or conceptual constraints, have been extensively studied in drawing with respect to the relations between the procedural flexibility (the extent to which children can modify or interrupt their ongoing drawing process) and the representational flexibility (the extent to which children can modify their internal representations). The third section focuses on this body of research.

Relationships between procedural and representational flexibility in drawing

The original Karmiloff-Smith study (1990) asked children to draw 'non-existent objects', thus requiring them to introduce innovations into their

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habitual way of drawing familiar objects (house, man, animal). The 4- to 6-year-old children responded to this requirement by introducing deletions of elements and/or changes in the size and shape of elements (intra-categorical changes). Older children (8–10 years) modified the position and/or orientation of elements, and, more interestingly, introduced new elements in their drawing coming from other conceptual categories, like, for instance, a house with wings (cross-categorical changes). She also reported that young children introduced their innovations at the end of their graphic routine, as if they were subjected to a procedural sequential constraint imposing a fixed ordering of the drawn elements at the executive level. By contrast, the older children interrupted their routine earlier in order to introduce their innovations. She suggested that the ability to introduce cross-categorical innovations, testifying to a high level of representational flexibility, was associated with the relaxation of the procedural sequential constraint, so that innovations could be introduced early in the drawing process, as well as with the relaxation of a constraint of independence occurring between drawing routines, so that they could share common pieces of knowledge. A RR process (representational redescription) was assumed in the Karmiloff-Smith model to account for this developmental transition between a first phase characteristic of the youngest children (implicit level) and a second phase characteristic of older children (explicit level), as well as between successive explicit levels. This theory inspired a lot of subsequent drawing studies, that tested whether young children were able to innovate at a cross-categorical level when explicitly asked to do just that (Berti and Freeman, 1997; Spensley and Taylor, 1999; Zhi, Thomas and Robinson, 1997) and whether they were capable of greater procedural flexibility than originally reported (Barlow, Jolley, White and Galbraith, 2003; Zhi *et al.*, 1997).

Also, for us, the Karmiloff-Smith paradigm was conducive to test further our three-steps developmental model as it emerged from the analysis of the local and global levels of organization of drawing. Vinter and Picard (1996) replicated the Karmiloff-Smith study in children aged 5, 7 and 9 years, aiming at more precision in the specifications of the innovations introduced in the drawings at the different ages. Seven types of innovations were observed and regrouped into three categories. The 5-year-olds mainly deleted, replicated elements and modified their shape or size, i.e. produced *element-based intra-representational* changes. The 7-year-olds also changed the position or orientation of the elements and modified the global shape of the depicted object, i.e. made *figure-based intra-representational* changes. At 9 years, children introduced elements coming from other conceptual categories (for instance, the house has wings) or assimilated the required object to depict another object (for instance, the entire house becomes a flower). These changes demonstrated the capacity to innovate at an *inter-representational* level. To test to what extent such a developmental sequence of changes could be paradigm-dependent, we used a different task (a deletion task) in a second study (Picard and Vinter, 1999), asking children to draw what remained visible from objects after a magician had made them partially invisible. A similar developmental sequence emerged from this last study, which showed that this sequence did not depend on the very act of drawing: using an eraser to produce the requested deletions on pre-drawn models led to similar results. We therefore considered that this sequence revealed internal changes in representational development.

Keeping with our model, it was tempting to try to link the inter-representational changes with the capacity to manage part–whole relations, an analysis that was supposed to sustain the third developmental step. Note that Spensley and Taylor (1999) argued similarly that cross-categorical innovations are related to a comparative analysis of the overall organization of the parts of one category with the overall organization of the parts of the other category. Thus, in order better to capture the nature of these inter-representational innovations, we investigated to what extent the ability to produce inter-representational changes was related to the ability to manage part–whole relations. Picard and Vinter (2006) hypothesized that if both abilities were related, a prior decomposition task devoted to the expression of part–whole analysis should enhance the production of inter-representational changes in a subsequent innovation task. In the priming decomposition task, children aged 5, 7 or 9 years were asked to draw familiar objects (a man, a house) split into two or several parts. A control group was required to draw just two other familiar objects (a bunch of flowers, a car) in the priming task. Then in the innovation task, both groups were requested to produce a 'man-house'. As expected, the children assigned to the priming decomposition task were better at producing inter-representational changes than the controls. The very activation of part–whole analysis processes in the prior decomposition task further benefited the management of inter-representational innovations because inter-representational flexibility is rooted in such segmentation abilities.

In what sense did the flexibility demonstrated at the executive procedural level, i.e. drawing as such, constrain the flexibility emerging at the representational level? Two quite separate aspects were rather confused in the Karmiloff-Smith notion of a sequential constraint in which relaxation should be essential for representational flexibility. This constraint could be expressed in a potentially fixed ordering of the elements within the drawing procedure. The relation of this aspect of sequential constraint

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with representational flexibility was revealed to be not evident. Zhi *et al.* (1997) reported that whether or not children succeeded at the innovation task (drawing a man with two heads), they tended to maintain a constant order in which the elements of their drawing were produced. Barlow *et al.* (2003) equally observed that the level of rigidity in the usual ordering of elements did *not* predict the capacity to produce subsequently representational changes. However, both studies did only analyse intra-representational changes, and did not deal with inter-representational changes. The second aspect of the sequential constraint refers to the capacity to interrupt early in the drawing process in order to introduce a novelty, rather than only at the end. From age 5, children were shown to be able to interrupt their procedure in the middle to insert a novelty (Berti and Freeman, 1997; Picard and Vinter, 1999; Spensley and Taylor, 1999; Vinter and Picard, 1996; Zhi *et al.*, 1997). However, some authors reported some associations between the production of more or less elaborated representational changes and the capacity to interrupt early the graphic routine.

Picard and Vinter (2007) investigated to what extent these two aspects of a sequential constraint were related to the expression of inter-representational flexibility in a series of four studies conducted with children aged 5, 7 and 9 years. The children were asked to produce inter-representational innovations in four conditions: (1) under verbal instructions ('draw a house with wings', for instance), (2) when 3D clay objects or (3) photographs of the 3D objects or (4) 2D contour line drawings of these objects were given as models to copy to the children. These four drawing conditions differed in terms of cost of the representational and procedural demands. They were the highest in the free task (no model at all), but lowest in the 2D contour line drawing task (because of the availability of ready-made models). The results showed that, in the free task, as the ability to introduce inter-representational changes improved with age, the capacity to interrupt the routine earlier to insert the novelties also improved. By contrast, whatever their age, children maintained relatively constant the sequencing of elements in their drawing procedures. When models were given to copy, inter-representational changes were globally enhanced, as well as the capacity to interrupt the routine, but no great changes occurred with respect to routine sequencing. Procedural rigidity declined as representational flexibility improved, and this decline occurred before the most sophisticated forms of representational flexibility emerged. The results also made clear that only the difficulty in interrupting routine progression could act as a constraint on representational flexibility. As claimed before, however, this constraint is probably only part of the process that leads to the expression of high-level, cross-categorical flexibility. The capacity to manage part–whole decomposition analysis also participates in this process.

In conclusion, whatever the level of analysis on which they focused, our experiments suggested a three-steps development in the capacity to plan and control drawing activity, that is, basically, a movement from processing elements to processing chunks of elements forming global units, and then to processing integrated wholes and parts. We consider that these developmental changes reflect the transformations intervening in the nature and in the size of the cognitive units that children manipulate when they process information and plan their behaviour. These changes would not be domain-specific, and some relations between drawing development and other non-verbal behaviours development are very likely. It is worth noting that the evolution we are pointing to with respect to drawing behaviour shares similarities with the one observed in prehension development for instance. Years ago, Vinter (1990) discussed prehension development in infancy, trying to show that changes in the way information is segmented into units sustain this development. This model can be summarized as follows. In a first step, young children (or infants) would parse information into small units or elements that tend to be isolated or juxtaposed one to the other. Limits in the attentional system are likely to explain this piecemeal parsing. Information parsing being reduced to elements, planning behaviour is locally or step by step organized, without any apprehension of the overall context. Anticipation is consequently strongly limited, and data-driven information processing dominates. Then, in a second step, associations between the previous elementary units are progressively established, and chunks are formed so that the overall organization of incoming information can be conceived of by children. Larger cognitive units are built. Associative learning such as implied in implicit learning surely contributes to this chunking process (see Perruchet and Vinter, 2002). Planning behaviour at a global level becomes possible, and anticipation increases. Mounoud (1988) has suggested that this chunk formation results in a temporary rigid functioning of children, as if their new capacity to represent reality as wholes prevented them from conceiving simultaneously its elements or parts. Finally, in a third step, children analyse progressively the previous global cognitive units in their parts so that relations between whole and parts as well as between parts of different cognitive units are elaborated. The cognitive units become flexible because they can be easily decomposed and recomposed.

In the last section of this chapter, a radically different viewpoint on graphic syntax will be adopted, showing how it can be modelled by experience. We will no longer consider graphic syntax as an indicator of representational development, but will show how it can become the content of incidental manipulations. This body of research concerns implicit learning, that is how, through repeated experiences, the behaviour of individuals becomes sensitive and adapted to a situation without any attempt actually to learn anything about it.

Syntax can be modified incidentally

Van Sommers (1984) discovered that the drawing of closed geometrical figures like circles shows an interesting regularity. If the starting point is set above a virtual axis going from 11 o'clock to 5 o'clock, right-handed subjects predominantly rotate counterclockwise. If it is located under this axis, most subjects' drawings rotate in the clockwise direction. Thus, this Start-Rotation Principle (SRP) (Van Sommers, 1984) implies that the direction of drawing movements is dependent on starting position. This syntactical regularity gains in strength between 4 and 10 years of age and is resistant to different experimental manipulations (Vinter and Meulenbroek, 1993). Between 70 per cent and 90 per cent of adults' production obeys this principle.

We further investigated whether the favoured direction of rotation could be modified by earlier directed practice. In a first experiment, adults were divided into three groups that differed as a function of their training phase (Vinter and Perruchet, 1999). While they thought they participated in a speed–accuracy graphomotor task, adults were required to trace, as accurately and as fast as possible, over a set of forty geometrical closed figures starting either at the top or at the bottom of the figures, and rotating in either a clockwise or a counterclockwise direction. Adults in the control group did not receive any indications with respect to where to start and how to rotate. Without them knowing it, adults in the two experimental groups either violated the SRP in 80 per cent of the cases (incongruent training), or respected the SRP in 80 per cent of the cases (congruent training). Then, following the training phase, the effects of the incidental manipulation were assessed by asking them to trace over the same figures but without any indications in terms of rotation. Only the starting point was imposed. Another test was also used, where only the direction of rotation was indicated, not the starting point. A large impact of training was revealed after the incongruent practice, inducing adults to invert the SRP, while no changes were found between training and test in the congruent training and control groups. A second experiment showed that this effect lasted for at least one hour, supporting the idea that the behavioural syntactical change was due to a genuine, albeit short-term, modification effect (Vinter and Perruchet, 1999). The very same pattern of results was obtained in children aged between 4 and 10 years (Vinter and Perruchet, 2000) as well as in mentally retarded children (Vinter and Detable, 2003).

Interestingly, the impact of training was obtained only in the starting point test, not when the rotation direction was used as a cue in the test. This was certainly due to the fact that the two movement parameters involved in the SRP are asymmetrically related, the driving of the starting position by the movement direction being harder than the reverse (Van Sommers, 1984). Thus, syntax can be changed by experience, but some of the basic procedural constraints inherent in the syntactical behaviour (here, the driving direction between starting point and movement rotation) cannot be modified.

A second interesting point was that young children, aged 4–5 years, followed the SRP less often than controls did, and they also were drawing more often according to the principle after congruent practice than controls. Their spontaneous level for respect of the SRP was not exceeding 50 per cent, compared to on average 70 per cent of the cases in older children and in adults. The high baseline level in older children and adults made a further increase in respect for the principle unlikely but left considerable room for a decrease. In contrast, the baseline in young children was close enough to random level to leave room for both an increase or a decrease. This suggests that syntax can be modified through an implicit learning episode even when developing. It does not need to be a stable behaviour.

Finally, we demonstrated that the very act of drawing, that is the executive motor component, was not necessary for inducing a change in syntactical behaviour (Vinter and Perruchet, 2002). Observing figures being drawn on a monitor screen in a way that either did or did not respect the SRP provoked the same type of incidental learning in children and in adults. The fact of having seen figures traced in a way violating the SRP in 80 per cent of the cases led the participants not to conform to the SRP when they had subsequently to draw the same types of figures. The success of this implicit observational learning procedure testifies to the fact that syntax organizes drawing behaviour at a central planning level, and not only at a peripheral, motor executive level, though it integrates the constraints operating at this executive level.

In conclusion, we would like to point out the richness of the study of graphic syntax in the drawing domain of research. Syntax is at the interface between high planning levels, including semantics and all conscious representational contents of thought, and low executive levels, including biomechanics and spatiotemporal organization of drawing movements. As such, it can provide useful information about how top-down and

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