



The development of children's perception of hierarchical patterns: an investigation across tasks and populations

Ira Puspitawati

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Ecole Doctorale Environnement, Santé, STIC (E2S)

The Development of Children's Perception of Hierarchical Patterns: An investigation across tasks and populations

Thèse de Doctorat de l'Université de Bourgogne
- Mention Psychologie –

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- 07 Octobre 2011 -



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GENERAL INTRODUCTION

PREAMBLE

The Development of Children's Perception of Hierarchical Patterns: An investigation across tasks and populations

Perception of hierarchical patterns has its roots in Navon's experiment that used patterns which present at a double level of organisation, a global one (the whole shape) and a local one (the elements that constitute the whole). Navon (1977) proposed that shape description is first constructed and recognized at the level of overall or global shape while the detailed processing of the smaller components would intervene later, as confirmed by the *global precedence effect*.

Nowadays, a growing body of research has expanded the concept and has confirmed the relative dominance of global processing over local processing. In our thesis, we investigated the relative dominance of these processes by considering the effect of age, stimuli properties, duration of exposure to the stimuli and gender in a perceptual task and a drawing task, and we tested these effects mainly from a typical and atypical developmental perspectives. Our objectives were to understand more comprehensively the developmental characteristics of children's perception through the global and local processing of hierarchical patterns.

Typical developing children as young as 3 years of age, until 10 years of age, participated in our first, second, third and fourth experiments. We investigated global/local processing at these ages since research in young children in this domain are still scarce and the results are mostly contradictory. Manipulation of the patterns, such as consistent vs. inconsistent and simple vs. complex, and also their durations of exposure (3 seconds for long duration and 300 msec for short duration) were meant to investigate in what extent these variables affected the relative dominance of global/local processing in children, in order to reveal the developmental milestones of children's global/local processing.

Our objective with regard to the involvement of atypical developing children with mental retardation as employed in our fifth experiment, was to investigate whether their global dominance responses which have been proved in other studies, could interfere with the automatic identification of familiar objects in meaningful patterns when they are located at the local level. We also aimed at analyzing whether the developmental aspects in processing at the global/local level were similar in these children to what was observed in typical developing children.

The last experiments of our thesis concerned the global/local processing in haptic perception in early blind children. To our knowledge, this is the first study concerning the global local processing in early blind children using Navon's stimuli. We aimed at revealing

whether these children showed a local tendency as reported in the adults with blindness. The results will also illustrate the developmental trajectories of global/local processing in haptic perception, since early blind children at 6 to 18 years of age participated in the study.

CHAPTER 1. General Introduction

I. Perceptual Organization : Some Historical Points

The history of perceptual organization started centuries ago when philosophers raised questions about the sources and validity of human knowledge. Epistemologists attempted to understand how things could be learned, whether there were innate ideas (as supported by rationalism) or whether the experience as the result of human's contact with physical world through senses would independently caused the learning process (as supported by empiricism), or whether both of them originated human knowledge (as supported by Kantianism).

Immanuel Kant (1781), in his work entitled *The Critique of Pure Reason*, stated that our understanding of the external world had its foundation in both the experience and a priori concepts. This led to the beliefs that our senses which were viewed as passive receptors, were actually active agents and pre-consciously attempted to make sense of their input as a result of brain's perceptual systems. Perceptual systems enabled organism to interpret and organize sensations to produce a meaningful experience of the world (Lindsay & Norman, 1977). While sensation points to the immediate and tends to be an unprocessed result of stimulation in our sensory receptors, perception refers to the process whereby sensory stimulation is translated into organized experience.

The organized experience, or percept, is the result of the joint product of sensory stimulations, and of the processing itself. The brain's perceptual systems are structured in a modular way, with different areas of the brain which process different kinds of sensory information, and these different modules are interconnected and influenced each other.

In general, there are two main approaches in explaining the process of perception, i.e.:

- Bottom-Up Approach: Perception is built from a set of primary features to a representation in our cognitive system without involving higher cognitive processes. It assumes a passive and automatic processing during perception. This approach which was also known as a data-driven approach was supported by Gibson (1979) with the *direct perception approach* and also by Marr (1982) who argued that high level perceptual experiences were derived from computations based on low level perceptions (such as edges and intensity changes).
- Top-Down Approach: Perception starts with a set of primary features but it is influenced by higher cognitive processes (such as knowledge, past experience and context). It assumes an active and volitional process at the basis of perception. This approach was supported by von Goethe, Mach and von Ehrenfels with a series of research by Wertheimer, Köhler,

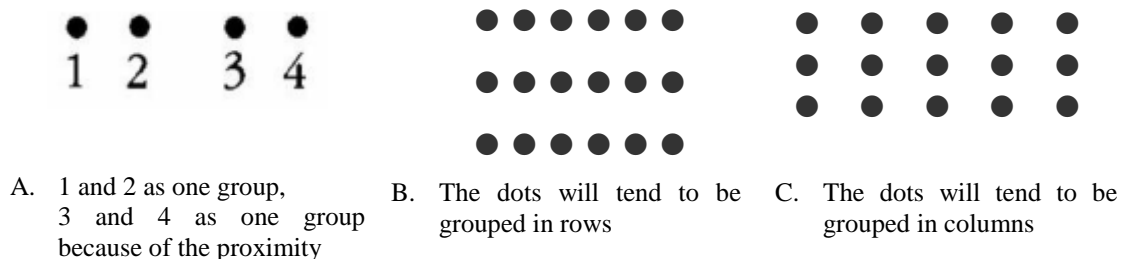
Koffka, and Lewin, who proposed the *gestalt principle*. Gregory (1997) also supported this approach with the *constructivist approach*, which stated that perception involves a process of constructing inferences from what we see. It involves an attempt of making a best guess or hypothesis about what we see. Prior knowledge and past experience are crucial in perception because when we look at something, we develop a perceptual hypothesis (which is based on prior knowledge and past experience), and the hypothesis can be confirmed or disconfirmed by the data we perceive.

The hypothesis referred to in the top-down approach triggered many researches to investigate the functional processes in the cognitive system. The most well-known research in the top-down approach was made by a group of psychologists who systematically studied perceptual organization in 1920's, in Germany. The concept of Gestalt was first introduced by Christian von Ehrenfels (1890), who proposed the concept of *Gestalt-Qualität* which refers to “form quality” or extra elements that accompanied the sensory processes and add bounding to the perceived object. This idea was then developed by Max Wertheimer in 1910, who concluded that the eye merely receives all the visual stimuli and the sensations are arranged by the brain into a coherent image. The law of *prägnanz* stated that the sensations are arranged in a manner that is regular, orderly, symmetric, and simple.

Gestalt psychologists, such as Wolfgang Köhler, Kurt Koffka, and Kurt Lewin, further refined Wertheimer's work to conclude that visual perception results from a process of organizing elements of sensations into various laws of grouping. The most important are the following :

- 1) **The principle of Proximity.** The principle of proximity or contiguity states that things which are closer together will be seen as belonging together as seen in Figure 1.

Figure 1. *Example of the principle of proximity*



- 2) **The principle of Similarity.** Similarity means a tendency to see groups which have the same characteristics. The principle of similarity states that things which share the same visual characteristics as shape, size, color, texture, value, or orientation are seen as belonging together to the same entity as described by Figure 2.

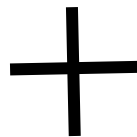
Figure 2. *Example of the principle of similarity*



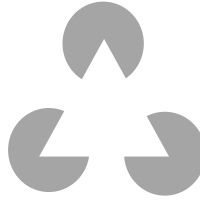
- A. Color characteristics will be seen as group B. Shape characteristics will be seen as group

- 3) **The Principle of Common Fate.** The principle of Common Fate stated that elements in the same moving direction are perceived as collective or as unit. An example of common fate can happen when someone perceives a green snake lying on the grass. When it doesn't make any movements, it will not be noticed. As soon as the snake begins to move, our brain organizes it as a figure against a background, so we can notice it immediately.
- 4) **The principle of Good Continuation.** The principle of continuity predicts the preference for continuous figures. People tend to perceive a figure as two crossed lines instead of 4 lines meeting at the center, when a cross pattern presented. Figure 3 illustrates this principle :

Figure 3. *Example of the principle of good continuation*

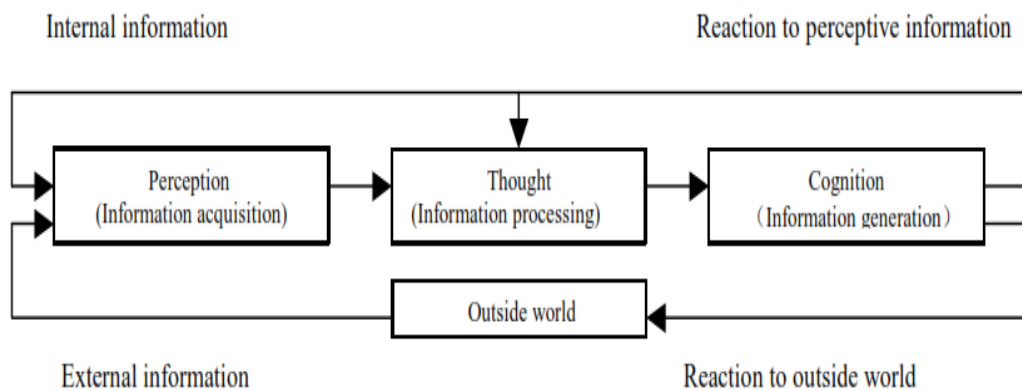


- 5) **The principle of Closure.** The principle of closure suggests that we tend to see complete figures even when part of the information is missing. This principle is related to the principle of good continuation when there is a tendency to fill-in missing information to make a whole. Figure 4 depicts an example of the Gestalt law of closure.

Figure 4. *Example of the principle of closure*

White triangle and three gray circles tend to be seen although they do not exist.

These gestalt principles are well-known for their ability to clarify the phenomenon of perception. But with the development of cognitive psychology and computational neuroscience in the 1950s and 1960s, the gestalt theory has been criticized for being descriptive rather than explanatory. The operating principle of Gestalt which states that the brain is holistic, parallel, and analog with self-organizing tendencies was also against the idea proposed by cognitive psychology which stressed the importance of past experience and knowledge as well as the reality stimulation about the outside world in generating the process of perception. Indeed, cognitive psychology sustains that bottom up processing (data driven processing) and top-down processing (concept-driven processing) are mutually included in the process of perception (Palmer, 1975; Norman & Bobrow, 1976; Lindsay & Norman, 1977). A general model of the cognitive procedure is reported in Figure 5 (Wang, 2002).

Figure 5. *General Model of Cognitive Procedure in Perception (Wang, 2002, p.75)*

Empirical evidences have supported the idea that perceptual processing must include both data-driven processing and concept-driven processing, so perception researches in cognitive psychology have mainly concentrated on the issue of pattern recognition. Human's pattern recognition can be treated as a typical perception process which depends on human's

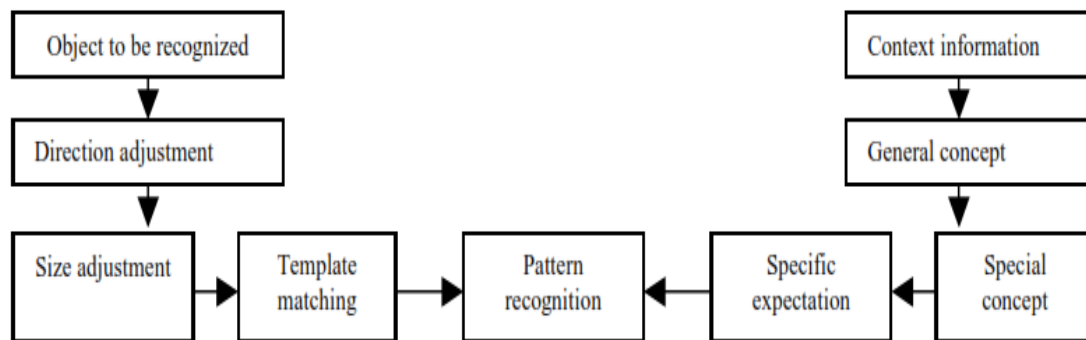
available knowledge and experience and cannot be just innate and self-organized as in the gestalt's view.

II. Perceptual Organization : Towards Contemporary Questions

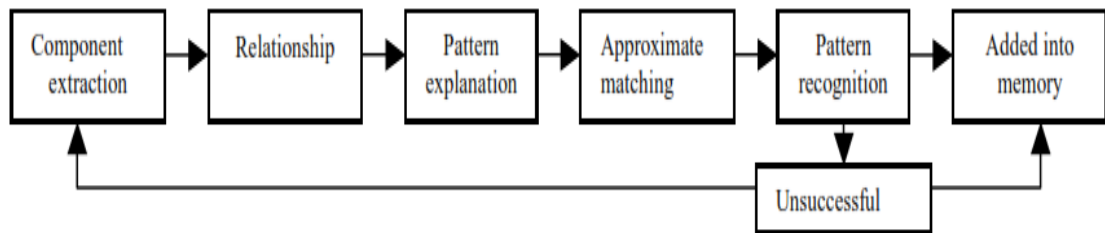
Modern cognitive psychology has proposed several theoretical models about human's pattern recognition, some of which are greatly affected by artificial intelligence. Among these models, we can mention the following :

- 1) **The Template-based Matching Model.** Human's memory stored plenty of various duplicates of real world patterns (templates). In the process of pattern recognition, the incoming sensory information is compared directly to the templates that have been stored in the memory. However, the real world patterns are various and may be different from the characteristics of the templates. If a corresponding template does not exist, the recognition of the pattern fails. Figure 6 depicts a template-based matching model.

Figure 6. *Template-based matching model (Wang, 2002, p. 76)*



- 2) **The Prototype-based Matching Model.** This model is also called the component-based matching model. This model was proposed in order to overcome the template-based matching because it is hard to explain an indisputable fact that people can rapidly recognize a new, unfamiliar pattern. With the prototype-matching, outside stimulation is only needed to approximately match the prototype, and a perfect matching is not required. Figure 7 describes the prototype-based matching model, which also shows a drawback since it is only contains bottom-up processing, so this is still being a dispute now.

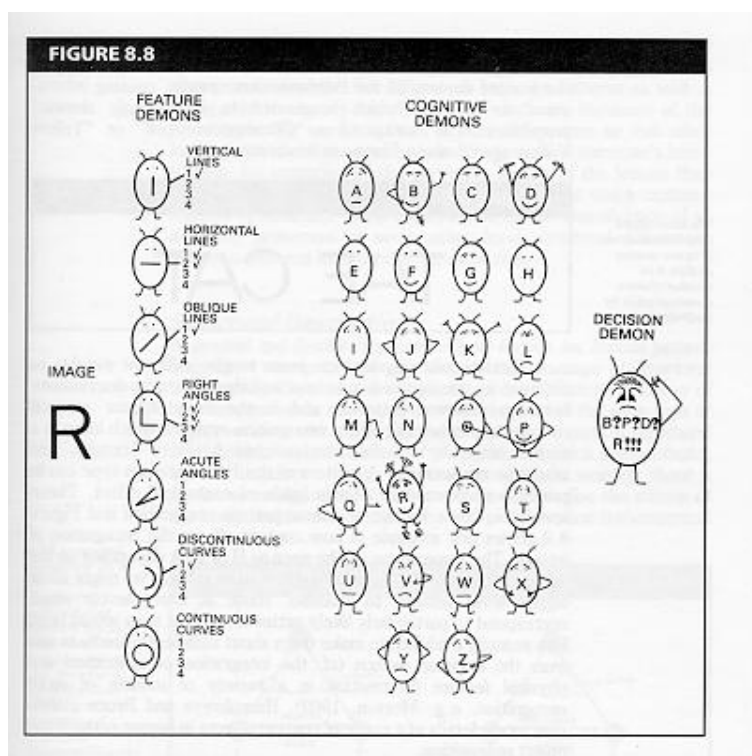
Figure 7. *Prototype-based matching model* (Wang, 2002, p. 77)

3) The Feature-based Matching Model. Features are elements or component parts which form a pattern. The relation among these elements or component parts can also be called features. The feature-based matching model considers that pattern recognition can be accomplished when all complicated stimulations can be analyzed through differentiated and separated features. Through the computation of features' existence and comparison of this calculation value with the list of known feature's value, a pattern can be recognized. The main difference between feature-based and template-based matching is that the pre-processing process can be easier and more flexible, since it is not necessary to consider the stimulation changes (by size, shape, etc.) because features and their relationships can be used as bases for matching and not the whole template necessarily. However, the same features can appear in different patterns, which can greatly lighten the burden of memory. It has greater flexibility compared to the other pattern recognition models, but unfortunately when different patterns have the same feature, it can lead to difficulty in recognition and can cause wrong recognition. A feature-based matching model is described in Figure 8, by the Pandemonium Model (Selfridge, 1959) which proposed that "four demons" involved in pattern recognition :

- **Image demons** for the process of raw sensory input
- **Feature demons** for the process of feature extraction
- **Cognitive demons** for the process of pattern generation
- **Pattern demons** for the process of pattern identification

Figure 8. *Feature Based Matching Model as in Pandemonium Model*

(Figure taken from <http://www.psych.utah.edu/psych3120-classroom/pandemon.gif>)

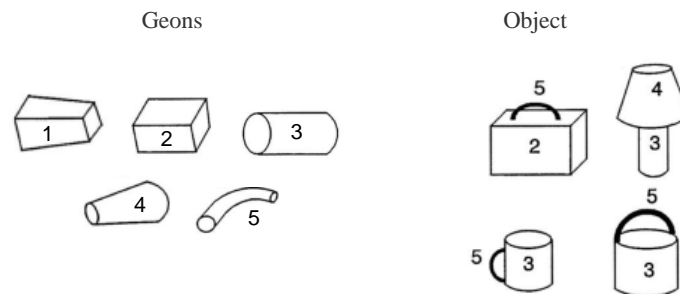


In this overview, it is interesting to mention a last model, that leads to the idea that pattern recognition (the whole) derived from an analogy of the combination of parts (local structures). Irving Biederman (1987) proposed the Recognition-by-Components Theory (RBC) that can relate the classic principles of perceptual organization and pattern recognition. RBC theory states that perceptual recognition of object is conceptualized as a process of segmenting the image of the input into an arrangement of simple 3D geometric components such as blocks, cylinders, wedges, and cones as described in Figure 9. A modest set of generalized-cone components called *geons* (geometrical-icons) can be derived from contrasts of five readily detectable properties of edges in two-dimensional image, which are:

- Curvature (various points of curves)
- Collinearity (points branching from a common line)
- Symmetry, and Asymmetry
- Parallelism (two or more points which follow same direction)
- Contermination (a point at which two points meet and therefore cease to continue)

These properties are generally invariant over any viewing position, image quality, and consequently allows robust object perception when the image is projected from a novel viewpoint when it is degraded. This is known as *viewpoint invariance* which enables us to recognize objects regardless of the viewing angle.

Figure 9. *Example of geometric icons (geons) in Recognition-by-Components Theory* (Picture taken from : http://eco.psy.ruhr-uni-bochum.de/download/Guski-Lehrbuch/Abbildungen/Abb_6-82.jpg)



The RBC theory states that structural descriptions of objects are stored in human memory. It involved an analysis of the relations between the parts of the object, followed by an analysis of its structure and a search for the best structural match to recognize an object. This approach proposes that recognition of the overall configuration of “parts” of a scene could facilitate the recognition of the objects.

This idea seems contra-intuitive with the phenomenon of *global precedence* described by Navon (1977). In his experiment using hierarchical letters as shown in Figure 10, Navon (1977) reported a priority of processing the global structure rather than the local details.

Figure 10. *Navon's Compound Letter*



Navon (1977) found that the nature of the large letter could interfere with decisions about the small letters, but the small letters had no effect on decisions about the identity of the large one. These findings propose that shape descriptions might be first constructed and recognized at the level of overall or global shape while the detailed processing of the smaller components would intervene later.

III. Perceptual Organization : The Navon's Approach

Navon's approach is based on the early studies of *Aktualgenese* which referred to the actualization of cognition that retraces growth patterns in phylo-ontogeny. Flavell and Draguns (1957) stated that thoughts and perceptions undergo a microdevelopment which is very brief, but theoretically important. This is an important point which differentiates Navon's theory of global-to-local processing from the previous Gestalt theory, although at the surface, they seem to deal with the same idea that perception is a top-down process. Gestalt theory fails to elaborate on the developmental aspect in perception, as some criticism conveyed (Ash, 1998).

The functional importance of global-to-local processing lays on the fact that human perceptual processors do not passively receive input but actively select which parts of the surrounding stimulation is worth to be received, attended and processed, or in other words, perception is basically dynamic. An empirical evidence that laid the global/local processing approach of Navon was the word-letter phenomenon which was an excellent demonstration of how word improves recognition of letters (Reicher, 1969; Wheeler, 1970). The pandemonium approach by Selfridge (1959) showed that similar patterns can be interpreted as two different letters depending on the context, which proves that the perceptual system ignores the details that are inconsistent with the interpretation indicated by the context. It supported the work by Pillsbury (1897) who demonstrated that readers might not be disturbed by omission or the substitution of letters in the text they read. Palmer (1975) showed that interpretation of ambiguous elements of a picture tended to the semantic structure of the whole scene even when it was distorted or when some details were deleted.

Navon evidenced that global features are perceived before the local ones because there are indications that people can take advantage of peripheral information (Williams, 1966; Rayner, 1975) and within the angular span that can be perceived with high acuity in just one fixation, there seems to be a progression with exposure time from a very gross to very fine-grained recognition.

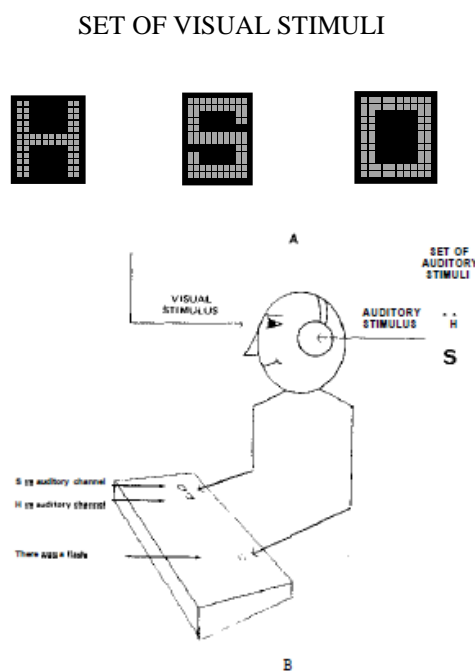
Motion perception also led Navon to the conclusion that the global is processed before the local. In his experiment (Navon, 1976), it was found that in situations of ambiguous apparent motion, the global features had the effect of determining the type of motion experienced, while figural identity of the elements did not give the same effect.

Research by Meili-Dsworetzki (1956) with children at different ages responding at several ambiguous figures (e.g. a man made out of fruits), supported Navon's hypothesis because the results showed that children perceived wholes at an earlier age than parts. However, the work of Elkind, Kogler and Go (1964) found opposite effects with different set

of figures. These empirical evidences led Navon to a conclusion that the general problem with these experiments was the lack of proper control over the stimulus material since global and local structures might differ in *complexity, salience, familiarity, recognizability* or *relative diagnosticity* for determining the identity of the whole (Navon, 1977, p.358). To overcome that problem, Navon proposed two major principles in his experiment, i.e. (a) control the global and local features and (b) independence of global and local features, so that the whole cannot be predicted from the elements and vice versa. In his seminal work, Navon (1977) conducted 4 experiments to prove the *global precedence effect*. He constructed tasks in which visual perception was restricted by visibility conditions and by limited attention in perceiving a compound letter (large letters that were made out of small letters).

In the first experiment, the participants were presented with letters on a Tektronix oscilloscope with a fast decay phosphor while listening to the utterances of the name of the letters H and S randomly (auditory stimuli vs. visual stimuli). Each subject faced three conditions of temporal overlap between the auditory and the visual stimuli : -40 msec, 0, or 40 msec. There were also three consistency levels (a) consistent, if the auditory stimulus consisted of the same letter than the visual stimulus; (b) conflicting, if the auditory stimulus differed from the visual stimulus; (c) neutral, if the visual stimulus was a rectangle. A schematization of the experimental task in Experiment 1 is described in Figure 11.

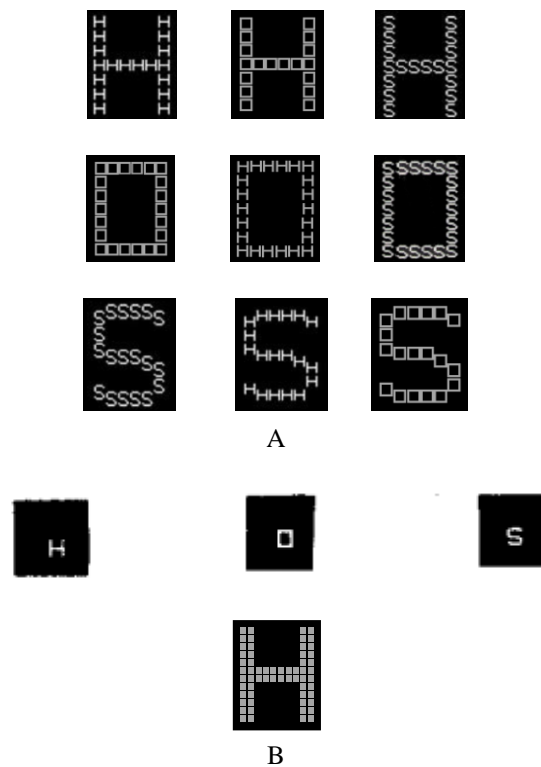
Figure 11. A Schematization of the experimental task in Navon's first experiment (Navon, 1977; p. 360)



The results showed that the conflicting level led to increases of the reaction times in the auditory condition while the consistent levels led to the lowest reaction times.

The second experiment had the main characteristics as Experiment 1 (procedure, apparatus, and setting). The difference was in the set of visual stimuli used, because the stimuli had a global shape made of local characters. The subjects were given three consistency levels like in Experiment 1, with patterns illustrated in Figure 12.

Figure 12. *A. The set of stimuli in Navon's second experiment (part 1)*
B. The set of stimuli in Navon's second experiment (part 2)
 (taken from Navon, 1977, page 365)



The second experiment included 2 parts; the first part used the global and local characters as described above, and the second part employed only one small letter (same size as local character) or one large bold letter (same size as the global level). When the subject was exposed to the global/local character, the results showed the high impact of the effect of consistency of auditory stimuli at the global level, but not at the local level. In the second part, the results showed that the effect of consistency was still highly significant, but it did not interact with the type of stimuli (small or large), demonstrating that it was not the smaller size of the elements per se that made them relatively or absolutely unnoticed in the global precedence effect (Navon, 1977, p.368).

The third experiment was designed to reveal whether the subjects had control on their own perceptual processes if any supplementary demand was employed during the experiment. The auditory stimuli were removed in the third experiment. In the *global-directed condition*, the subject was supposed to indicate whether the global character was H or S (the rectangle global shapes were not used). In the *local-directed condition*, the subject was supposed to indicate whether the local character was H or S (the rectangle local shapes were not used). The results showed that the global character was recognized faster than the elements. Subjects processed the global pattern without being affected by the local features while they were not able to process the local patterns without being aware of the global character. This revealed that attention could not be efficiently diverted from the whole and proved that global processing was a necessary stage of perception. The local features could still be processed if a strong effort was made.

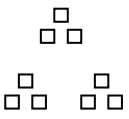


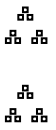








The fourth experiment intended to examine whether there was any condition under which the local features could be processed less thoroughly than the global features, although both levels were equally critical for performance. The “same-different” judgements on pairs of patterns as presented in Figure 13 was used in a task that required the subject to place equal importance on both levels.

Figure 13. *Set of stimuli in Navon's fourth experiment*

Relationship	Target Stimulus	Probe Stimulus
SAME		
GLOBALLY DIFFERENT		
LOCALLY DIFFERENT		

The target and probe stimuli could be displayed simultaneously or sequentially and the subjects were asked to decide whether the patterns were the same or different. In the fourth experiment, Navon also designed a control session which used the same task, but he added two conditions: a *spatial certainty* condition where the patterns appeared at the centre of the field, and a *spatial uncertainty* condition, where the patterns appeared randomly in the field. To control the subject's readiness, Navon employed two conditions which were *temporal certainty* (subjects were given both an auditory warning and fixation point before each trial) and *temporal uncertainty* (when subjects did not have any warning signal). The examples of the display in each condition and session in Experiment 4 are described in Figure 14.

Figure 14. *Examples of the displays in each condition and session of Navon's fourth experiment 4 (Navon, 1977, p. 374)*

	<i>Sequential Presentation</i>		<i>Simultaneous Presentation</i>	
	<i>Large Size</i>	<i>Small Size</i>	<i>Horizontal Comparison</i>	<i>Vertical Comparison</i>
Prototypical display in test or practice sessions				
Prototypical display in control session with spatial certainty				
Prototypical display in control session with spatial uncertainty				

The results indicated clearly that the global differences were detected more frequently than the local differences. The short exposure resulted in a difficulty in processing the local elements despite that the spatial and temporal certainty conditions were meant to motivate the subjects to process at the local level. In the conditions of spatial uncertainty and temporal uncertainty, the longer exposures also led to more global than local processing. So the effect was not due to the fact that the global patterns were more likely to be perceived in case of brief exposure, since longer exposure also led benefitted to global processing.

On the basis of these four experiments, Navon suggested that only the global level was subject to interference by the auditory discrimination response. This global precedence effect is not an inherent property of visual perception because when subjects had to respond either just to the global level or just to the local level, the identity of the global cues that conflicted with the local ones inhibited the response to the local level, while the recognition of the local identity had no effect on global recognition. This confirms that people cannot skip global processing. Processing at the local level could operate if a deliberate attempt was made as shown in the last experiment, but the global differences were detected more often than the local ones. These results support the idea that global processing is done before more local analysis is completed and they constitute a body of evidence supporting the notion of global precedence.

The work of Navon (1977) has opened a new beginning in the history of perceptual organization. It opened a broad area of research in perceptual organization in cognitive, developmental, and clinical psychology.

IV. Global and Local Processing in Hierarchical Patterns : State of the Art

Many researches have been performed in the domain of hierarchical stimuli to reveal the *global precedence effect* since it has been proposed by Navon (1977). Hierarchical stimuli are patterns which present a double level of organisation, a global one (the whole shape) and a local one (the elements that constitute the whole). The *global precedence effect* refers to the tendency to process the whole before the parts.

The global precedence hypothesis proposed by Navon (1977) had also been developed from the earlier assumption on serial processing (processing resources were first engaged with global information, and processing of local information was optional) but later the possibility of parallel processing of global and local information was suggested (including Navon, 1981), with the global information being processed faster and thus being available earlier than the local one.

Global precedence hypothesis has been confirmed in a large body of research although it could depend on retinal location (Pomerantz, 1983; Grice, Canham, & Boroughs, 1983), on the type of stimuli (Kimchi & Palmer, 1982; Martin, 1979; Kimchi, 1988; Lamb & Robertson, 1988; Lamb, Yund, 1993; Love, Rouders, & Wisniewski, 1999; Poirel, Pineau, & Mellet, 2008), on the task given at test (Martin, 1979; Hoffman, 1980; Navon, 1983; Kimchi, 1988; Farran, Jarrold, & Gathercole, 2003), on the duration of exposure of the stimuli (Pomerantz, 1983; Paquet & Merikle, 1984; Ninose & Gyoba, 2003), and on developmental aspects (Dukette & Stiles, 1996; Kramer, Ellenberg, Leonard, & Share, 1996; Tada & Stiles, 1996; Burack, Enns, Iarocci, & Randolph, 2000; Mondloch, Geldart, Maurer, & de Schonen, 2003; Porporino, Shore, Iarocci, & Burack, 2004).

The nature of the stimuli in the global/local paradigm remains an interesting subject of research (Navon, 1983; Kimchi, 1988; Dukette & Stiles, 1996; Love et al, 1999; Dukette & Stiles, 2001; Grill-Spector & Kanwisher, 2005; Poirel, Pineau, & Mellet, 2006, 2008), as the task given during the experiment (Kinchla & Wolfe, 1979; Grice et al, 1983; Pomerantz, 1983; Kimchi, 1988; Sanocki, 1993; Weber, Schwarz, Kneifel, Treyer, & Buck, 2000; Ninose & Gyoba, 2003). We will envisage these two aspects in our thesis.

Nowadays, the global/local paradigm has broaden its field of application; not only in the field of visual processing but also in auditory processing (List, Justus, Robertson, & Bentin, 2007; Sanders & Poeppel, 2007), including music perception (Deruelle, Schön, Rondan, & Mancini, 2005). It has also been applied to different cultures (Davidoff, Fonteneau, & Fagot, 2008; McKone, Davies, Fernando, Aalders, Leung, Wickramariyaratna, & Platow, 2010) and different individuals, especially older adults (Georgiou-Karistianis, Tang, Mehmedbegovic, Farrow, Bradshaw, & Sheppard, 2006) and psychopathological cases

like prosopagnosia (Duchaine, Yovel, & Nakayama, 2007), individuals with mental retardation (Birhle, Bellugi, Delis & Marks, 1989; Porter & Coltheart, 2006; Dulaney, Marks, & Devine, 1994) and individuals with schizophrenia (Poirel, Brazo, Turbelin, Lecardeur, Simon, Houdé, Pineau, & Dolfus, 2010). However, the global precedence hypothesis was not confirmed in individuals with early and late blindness by using haptic perception of form (Heller & Clyburn, 1993), individuals with autism and Asperger Syndrom (Iarocci, Burack, Shore, Mottron, & Enns, 2006; Behrmann & Kimchi, 2003; Deruelle, Rondan, Gepner, & Fagot, 2006; Rondan & Deruelle, 2007; Scherf, Luna, Kimchi, Minshew, & Behrmann, 2008), individuals with William Syndrome (Rondan, Santos, Mancini, Livet, & Deruelle, 2007; Farran et al., 2003), with Alzheimer's disease (Slavin, Mattingley, Bradshaw, & Storey, 2002), individuals with obsessive compulsive personality (Yovel, Revelle, & Mineka, 2005), individuals with simultanagnosia (Jackson, Swainson, Mort, Masud, & Jackson, 2004; Dalrymple, Kingstone, & Barton, 2006) and individuals with visual agnosia (Aviezer, Landau, Robertson, Peterson, Soroker, Sacher, Bonneh, & Bentin, 2007).

In the last thirty-years, many researchers have investigated the issue of local-global processing with Navon's stimuli and they have concluded that a variety of factors affect the global advantage effect. These factors are related to the stimulus and to the type task given at test. The main factors that have been investigated are the following :

- 1) **Overall Visual Angle.** The works of Kinchla & Wolfe (1979), Navon & Norman (1983), and Lamb & Robertson (1990) found that global and local reaction times depended on the set of visual angles presented. Global advantage was found with patterns subtending less than 7° of visual angle and a local advantage was found with larger patterns, of about more than 10° of visual angle.
- 2) **Retinal Location (foveal vs. peripheral).** Pomerantz (1983), Grice et al.(1983) and Lamb & Robertson (1988) concluded that retinal location could affect the relative speed of processing. Global advantage was obtained with peripheral presentation, but not with central presentation. This result concerning retinal location indicated that there are relations between the foveal (central) vs peripheral location and spatial uncertainty (this resembled to Navon's fourth experiment). Spatial uncertainty led a global search through the peripheral area although the stimuli were presented in the fovea (central). This result led to broader studies because other aspects like eccentricity and acuity of the stimuli were suspected to influence the results in retinal location (Navon & Norman, 1983).

- 3) **Sparsity and number of local elements.** Martin (1979), Navon (1983), and Kimchi (1988) examined the effect of sparsity (the spacing between local elements) using a stroop-like task, a same-different task, and a simultaneous comparison task. Martin (1979) reported global advantage with less sparse elements while local advantage emerged with the sparse ones. This result supported Navon (1983) although the shape of the elements appeared to play an important role (the triangular patterns were influenced by sparsity but not the rectangular patterns). Kimchi (1988) suggested that sparsity and the number of local elements, other factor such as the contours of the global figure, the task demands and the “goodness” of the global figure might have an effect.

- 4) **Goodness of form.** The “goodness” of the shape of the figure might have an effect in the global advantage effect and it has been investigated by Hoffman (1980), Sebrechts & Fragala (1985), and Poirel et al. (2006) using several tasks (e.g. memory scanning task, sequential same-different task, identifying the identically pairs of items). “Good patterns” were processed faster when they constituted the relevant level and when the level of processing was irrelevant, good patterns slowed down the responses because of stronger response competition (Sebrechts & Fragala, 1985). The stimuli could also be either objects or non-objects (meaningfulness of the stimuli) and the results with children showed that the development of children’s visual perceptual processing progressively evolved from a local preference at age of 4 to a global preference at age of 9 when objects or non-objects stimuli were used (Poirel, Mellet, Houdé & Pineau, 2008).

- 5) **Duration of exposure to the stimuli.** Pomerantz (1983) and Paquet & Merikle (1984) showed that interference between the global and local letters was affected by exposure duration. When they presented compound letters for 10, 40, or 100 msec, unidirectional global to local interference was found at the shortest exposure duration.

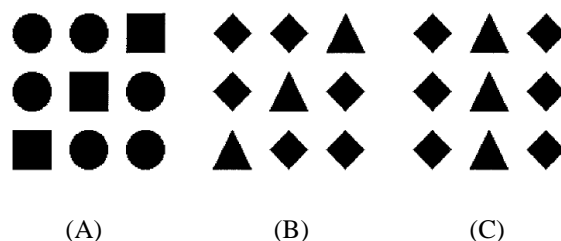
- 6) **Attention Allocation.** According to the work of Hoffman (1980), Ward (1982), Kinchla, Solis-Marcia & Hoffman (1983), Paquet & Merikle (1984), Robertson (1996), and Ninose and Gyoba (2003), the direction of attention to the global and local level of an object determined which level was processed first (global or local). So, it was concluded that attention played a role in the effect of global advantage.

- 7) **Conspicuity of the stimuli.** There are several works related to the role of conspicuity of the stimuli with regard to the global advantage effect. Many studies related conspicuity to the difference of spatial frequency caused by the size of the elements (of the local and

global elements) or their contrast-luminance (Hoffman, 1980; Schyns & Oliva, 1994; Lamb & Yund, 1996). Hoffman (1980), Sanocki (1993) and Schyns and Oliva (1994) manipulated the sizes of stimuli and found that when the subject was presented with small and medium sizes, then a global advantage was obtained with the small sizes and a local advantage with the medium sizes. When the subject was presented with medium and large sizes, then a global advantage was obtained with the medium sizes and a local advantage with the large sizes. This proved that medium size stimulus could be processed both locally and globally. Other research has relied on the conspicuity of the stimuli based on contrast balanced theory (Lamb & Yund, 1993, 1996; Lamb, London, Pond, & Whitt, 1998). Contrast balanced stimuli are stimuli in which the low spatial frequencies are eliminated so both the local and global forms must be identified using high spatial frequency information. The results showed that the global advantage in the nested letter was achieved if the nested letter stimuli were written on grey paper and the letter's colour was white, while the global advantage was not achieved if the white letter was outlined with black colour. The black outline is called *contrast balancing* and the effect reduced the spatial frequency (lower spatial frequency).

- 8) **Structure or relational properties.** In the Gestalt theory, similarity and proximity elicit processes which confirm that the processing of the global pattern precedes the processing of the local pattern. In the work of Love et al. (1999), geometrical shapes were used as local elements to reveal the role of relational properties. Using a same-different task, subjects had to decide whether the two patterns were the same or different. Figure 15 illustrated the stimuli.

Figure 15. *Illustration of stimulus in the relational properties experiment (from Love et al, 1999, p. 293)*



A and B have the same diagonal relational properties while C has vertical relational properties. When the stimuli are presented, the subjects should answer “the same” for A and B and “different” for A and C or B and C in case of global advantage. The results confirmed that global advantage is a process of grouping.

Let's examine now more precisely the works done in a neuropsychological and developmental perspectives.

A. Neuropsychological Studies in Global-Local Processing

The aims of the studies in neuropsychology that have investigated the global-local paradigm were not only to reveal which processes in the brain are activated when perceiving the global figure and local elements, e.g. the mapping location of the activated brain, as in the work of Han, Liu, Yund & Woods (2000), Lamb, Robertson & Knight (1990) and Robertson, Lamb & Zaidel (1993). They also aimed at revealing the neural substrates (Han, Yi, & Hua, 2004) and the development of hemispheric lateralization of these processes (Moses, Roe, Buxton, Wong, Frank, & Stiles, 2002; Kimchi, Hadad, Behrmann, & Palmer, 2005).

With regard to hemispheric differences in the perception of global/local information, some authors concluded that the right hemisphere (RH) was faster and more accurate in the identification of global components of the input and the left hemisphere (LH) was faster and more accurate in the identification of the local components (Lamb & Robertson, 1988; Robertson et al., 1993; Yovel, Yovel, & Levy, 2001). Evidence from a variety of different methodologies supported this hypothesis that the RH is biased toward the processing of global input characteristics while the LH is biased toward the processing of local input characteristics. The spatial frequency characteristics of the stimuli could also explain the difference in processing global/local information. Lamb and Yund (1993) examined the role of spatial frequency using the contrast balanced stimuli as explained before. Contrast balancing selectively removes low spatial frequency information. Thus, both local and global processing of the stimuli must be performed on the basis of high spatial frequency information alone. Removal of low spatial frequencies significantly disrupted global level processing, suggesting that the global advantage might result from a temporal advantage in the processing of low spatial frequency information.

The results proved that both hemispheres seem to be able to process a large range of stimuli, with differences arising between hemispheres for certain types of stimuli and/or greater efficiency for certain processes. In general, the RH seems to be biased to distribute attention over larger portions of the visual input than the LH, which seems to process object 'parts' more effectively. Together then, spatial frequency and attention consideration predict that the RH will create categories on the basis of more 'holistic' similarity (whole-object, whole-shape, etc), while, in contrast, the LH seems likely to categorize more readily on the basis of distinctive features (similarity of parts, details).

The work by Han et al. (2004) regarding the substrates involved in global/local processing showed that attention to the global level of bilateral visual inputs induced stronger activation in the left and right temporal cortices. Attention to the local level generated stronger activation in bilateral superior parietal cortices. These results suggested that distinct neural substrates in the temporal (for global) and parietal cortices (for local) were preferentially engaged in the global and local processing of bilateral visual inputs.

In relation with the development of the brain, Moses et al. (2002) found that children of 7 to 14 years of age demonstrated an emerging pattern of hemispheric differences. Children's development was characterized by a left hemisphere advantage for the local level processing that resembled the adult's one and a trend towards a right hemisphere advantage for global processing. Children with Immature Bilateral (IB) hemisphere showed greater overall activation for local level processing, balanced activation across the two hemispheres for the global condition, and a trend of greater activation for local processing in the right than the left hemisphere. In contrast, in children with Mature-Lateralized (ML) hemisphere, the right hemisphere showed greater activation than that in the left one during global analysis and the opposite during local processing. This demonstrated a shift from undifferentiated bilateral processing toward hemispheric lateralization in children from 7 to about 12 to 14 years of age where a period of notable transition was marked. This confirmed previous studies of spatial cognition in children which noted that children are capable to process at global and local level of analysis and that the relative use of these processes changes with age (Moses et al, 2002).

B. Developmental Studies in Global-Local Processing

Issues concerning the development of local and global perception were typically centred on the question of the priority of hierarchical level. One early view was that children are primarily holistic or global processors, evidenced by infants' initial focus on the external contours of line drawings and later inclusion of interior details (Quinn & Eimas, 1998; Porporino et al., 2004). This notion of global precedence supported the evidence that young children tended to categorise objects on the basis of their overall similarity rather than on the similarity of the components (Smith & Kemler, 1977).

However, the developmental sequence between local and global processing is more complex than originally suggested (Burack et al, 2000). Young children could attend to both global and local attributes under appropriate conditions (Tada & Stiles, 1989; Stiles, Delis, & Tada, 1991, Dukette & Stiles, 1996), but they showed impairments under certain conditions. For example, Prather & Bacon (1986) found that children between the ages of 2 years 7 months and 5 years 7 months were able to name both parts and whole of simple pictures, but

were less efficient in the naming of both aspects in more difficult pictures. This indicated that the capacity to perceive multiple aspects of a display could depend on the stimulus or task complexity.

Dukette and Stiles (1996) examined the development of young children's analysis of spatial patterns, specifically hierarchical letters and geometrical forms. With a forced choice task, specific stimulus manipulations were introduced to assess children's ability to segment and integrate hierarchically organized information under different conditions (computerized version vs. pencil and paper version). The results showed that children as young as 4 years of age demonstrated substantial analytic competence. However, although they were able to integrate the parts of the spatial array to form a coherent whole, the ability was weaker and more easily disrupted than in older children and in adults.

This result was also supported by the work of Tada and Stiles (1996) that examined the early development of spatial patterns analysis and focused on how pre-school children segmented and integrated the parts of simple spatial forms. They showed that young children analyzed spatial patterns in ways that differed systematically from older children and adults. The youngest children segmented out simple, well-formed, spatially independent parts and used simple relational structures to bind these parts together. With development, children constructed forms that included increasingly complex parts and relations.

Kramer et al. (1996) investigated the developmental sex differences in global-local perceptual bias. Previous developmental studies showed that boys tended to perform better than girls on tasks associated with the right hemisphere (spatial task), whereas girls performed better on tasks associated with left hemisphere (verbal task) (Denckla & Rudel, 1974; Kirk, 1992). Kramer et al. (1996) showed that boys were significantly better at processing global information than girls at all ages (4 – 12 years) and younger children of both gender were less capable at processing global information than older children. This is consistent with developmental models that suggest an early left-hemisphere advantage for girls and a right-hemisphere advantage for boys.

V. Our approach

The growing body of research around Navon's *global-local paradigm* testifies for the interest of this paradigm in the understanding of human's perception. In the domain of cognitive psychology and developmental psychology, there are still a lot of questions that need further research.

The study of perceptual organization of parts versus whole in developmental psychology was originally triggered by questions regarding the development of general visual

processing. Some early studies proposed that young children had limited ability in perceiving objects, so they would be able to attend to either only the whole, without the analysis of the local parts (Gibson, 1979; Vurpillot, 1976), or only to the parts without a comprehensive picture of the global shape (Diamond & Carey, 1977; Elkind et al, 1964). The results of recent studies have indicated that these contradictory conclusions were more likely due to variations in stimulus complexity rather than to the limitations in children's perception. Indeed, preschool-age children seem able to attend to both the part elements and the whole shape in visual perception task (Dukette & Stiles, 1996; Prather & Bacon, 1986; Tada & Stiles, 1996; Tada & Stiles-Davis, 1989). Some studies indicate that part and whole processing, developed throughout early ages until late adolescent (Harrison & Stiles, 2009; Mondloch et al., 2003; Porporino et al., 2004; Scherf et al., 2009), but studies with younger children at pre-school ages are scarce (Hadad & Kimchi, 2006; Farran & Cole, 2008).

Previous studies also showed that children's perception seems to be influenced by stimulus complexity and by the type of task administered during the experiment (Prather & Bacon, 1986; Kinchla & Wolfe, 1979; Grice et al., 1983; Pomerantz, 1983; Kimchi, 1988; Sanocki, 1993; Weber et al., 2000; Ninose & Gyoba, 2003). Further systematic investigations are still worth conducting, in particular with regard to the effect of the task used. We will systematically introduce drawing tasks because they have been very rarely used in children within this domain of research, although drawing was proposed to be an effective task in revealing the visual perception of typically and atypically developing children (Dukette & Stiles, 2001; Lange-Küttner, 2000; Porter & Coltheart, 2006).

Inter-individual characteristics affect children's visual perception. Some early studies showed that atypically developing children develop different patterns of visual perception compared to typically developing children. Children with Perinatal Right Hemisphere Focal Brain Lesions (RPL) were selectively impaired on global accuracy and children with Perinatal Left Hemisphere Focal Brain Lesions (LPL) on local accuracy (Stiles, Stern, Appelbaum, Naas, Hesselink, & Trauner, 2008). Individuals with WS (William Syndrome) do not have a local or a global processing bias when asked to identify stimuli, but do show a local bias in their drawing abilities (Farran et al., 2003). However, while Porter and Coltheart (2006) reported a local advantage in the drawings of individuals with WS, and also a local bias in a non-constructional task, individuals with Down Syndrome (DS) performed better in drawing the global shape than the local elements (Bellugi, Birchle, Jeringan, Trauner & Doherty, 1990; Bellugi, Lichtenberger, Jones, Lai, & St George, 2000), and children with autism displayed normal global processing but not normal local processing (Plaisted, Swettenham, & Rees, 1999). The literature in children with Down Syndrome is contradictory, and nothing is known about the local/global processing in blind children.

The experiments that have been done in the present thesis are an extension of those previous works to reveal further characteristics of the development of children's perception in hierarchical patterns across tasks and populations. Perceptual tasks (a similarity-judgment task or a naming task) and drawing tasks have been implemented in all four experiments.

Manipulation of duration of exposure to the stimuli was also introduced in Experiment 1 to Experiment 4 since previous studies showed that interference between the global and local patterns was affected by duration of exposure in adults (Pomerantz, 1983; Paquet & Merikle, 1984). A long duration (3 seconds) and short duration (300 msec) were applied with the typically developing children in Experiment 1 to Experiment 4, but no time restrictions were given to atypically developing children in Experiment 5 and Experiment 6. We assumed that, in a drawing task, longer duration elicited more local-global integrated or correct responses in children across ages while short durations directed these children to respond with more non-integrated responses. Prolonged exposure seemed to reduce the efficiency of global processing (Ninose & Gyoba, 2003), so we expected that, in a perceptual task, longer durations will also elicit local preference, while global preference will be more produced by the short durations.

Consistent and inconsistent visual hierarchical patterns were studied in Experiment 1 to Experiment 4 to reveal the interference effects between the global and local level. Similar consistent and inconsistent hierarchical patterns were used in Experiment 6, but in the form of haptically explored hierarchical patterns since early blind subjects participated in the experiment. Our hypothesis was that the interference effect by the inconsistent stimuli will inhibit the integrated responses in children, while the integrated responses will be more produced by the influence of consistent stimuli.

Simple and complex hierarchical patterns were conveyed in Experiment 3 and Experiment 4 with typically developing children, since previous studies proposed that younger children segmented out simple, well-formed, spatially independent parts and used simple relational structures to bind these parts together (Tada & Stiles, 1996). Based on this assumption, we expected that older children will process globally the complex hierarchical patterns more efficiently than the younger children. Since this comparison between simple and complex stimuli in the studies of hierarchical patterns was new in the literature, we considered this part of our experimental work as highly exploratory.

Meaningful (familiar objects) patterns and non-meaning (non-objects) patterns were applied in Experiment 5 in order to reveal whether meaning elicited local preference and local interference as proposed by Poirel et al. (2006,2008). Children with mental retardation participated in this experiment. Considering that global responses were dominant in children with mental retardation (Birhle et al., 1989; Bellugi et al., 1990, 2000; Porter & Coltheart,

2006), we expected that meaning would elicit local preference in these children when meaningful objects were used as local elements.

The contradictory results in the literature regarding typically and atypically developing children also lead to an urge to study children's visual perception across populations. Typically developing children aged 3 to 10 years participated in Experiment 1 to Experiment 4, children with mental retardation aged 6 to 14 years participated in Experiment 5, and early blind children aged 6 to 18 years participated in Experiment 6. Typically developing children can attend to both the local and global level at younger ages, but the ability was more easily disrupted compared to older children or adults. This led to an expectation that there is an effect of age in children's responses to hierarchical stimuli. The local preference should be often found in the younger children compared to the older children and then global and more integrated responses should dominate. On the other hand, we expected that the atypically developing children with mental retardation would follow a global to a local analysis as age increased and should combine these analyses into integrated responses at older ages. Contradictory results were expected in atypically developing children with early blindness. Early blind adults were suggested to have dominant local responses (Heller & Clyburn, 1993), so we expected that early blind children would develop from non-integrated responses to local responses, and then, with the developing ability to respond at the global level, children should be able to integrate these responses in older ages.

EXPERIMENTAL SECTION

CHAPTER 2. Children's spatial analysis of hierarchical patterns: Construction and perception¹

Introduction

In this chapter, two experiments are reported that aimed at investigating the development of spatial analysis of hierarchical patterns in children between 3 and 9 years of age, using a drawing and a similarity-judgment task.

Drawing behavior has attracted the interest of developmental psychologists from the turn of the last century (e.g., Freeman, 1980; Lange-Küttner & Vinter, 2008; Luquet, 1927; Willats, 2005). An original use of this nonverbal behavior was to investigate the development of spatial analysis of hierarchical patterns in children (Dukette & Stiles, 2001; Lange-Küttner, 2000; Porter & Coltheart, 2006). The concept of hierarchical patterns can be traced back to Navon (1977), who designed compound figures made of large global letters (e.g., a large H that constitutes the global level) composed of small local letters that could be consistent (e.g., small Hs) or inconsistent (e.g., small Ss) with the global level to test the so-called "global precedence effect" (see also Kimchi, 1992; Martin, 1979; Navon, 2003). Indeed, Navon (1977, p. 354) argued that "perceptual processes are temporally organized so that they proceed from global structuring toward more and more fine-grained analysis." This hypothesis claims that when processing a visual object or a visual scene, the global properties are processed first, and the local properties are analyzed later. The originality of envisaging this issue through drawing behavior relies on the fact that drawing a hierarchical pattern, from memory or in a copying task, requires the integration of both processes, regardless of their respective priority in the very act of perceiving.

To our knowledge, only two studies have investigated how typically developing children draw hierarchical patterns. Lange-Küttner (2000) asked children 5, 6, or 11 years of age and adults to copy an inconsistent hierarchical letter pattern (a large H made of small Ss). She reported that 5-year-old children drew only the global shape of the pattern (H) in more than 70% of the cases and that correct reproduction of both levels was observed at 11 years of age. Dukette and Stiles (2001) asked children 4–8 years of age and adults to copy inconsistent hierarchical patterns or to draw them from memory. Under constrained task conditions (a memory condition compared with a copying condition), the youngest children had more difficulties in reproducing the global shape than the local elements, though they were able to attend to both levels of analysis. When making the local level more salient by decreasing the

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density of elements, the local advantage increased and was still observed at 8 years of age. These results diverge from those by Lange-Küttner (2000). It is thus yet unclear whether young children would manifest an initial local or global bias in their drawing of hierarchical patterns and to what extent both levels would be present in the drawings.

The other studies that have used drawing behavior for investigating this question were concerned with neuropsychological issues. Several authors reported that children with William syndrome (WS) were more accurate in drawing the elements than the global shape of patterns (Bellugi, Sabo, & Vaid, 1988; Bihle, Bellugi, Delis, & Marks, 1989), whereas individuals with Down syndrome performed better in drawing the global shape than the local elements (Bellugi, Bihle, Jeringan, Trauner, & Doherty, 1990; Bellugi, Lichtenberger, Jones, Lai, & St. George, 2000). Farran, Jarrold, and Gathercole (2003) confirmed the finding with individuals with WS and reported another interesting result: This local bias was shown only in drawing, not in a perceptual task requiring stimulus identification. Farran et al. suggested that the local bias observed in drawing was not due to perceptual processing but from a difficulty in integrating the parts into a whole when producing a drawing. However, Porter and Coltheart (2006) reported a local advantage in the drawings of individuals with WS and also a local bias in a nonconstructional task. This latter result questions the hypothesis that the local bias in drawing could be due to the constructional nature of this task. To our knowledge, there is no study with typically developing children in which performance was compared in a perceptual and in a constructional drawing task using the same hierarchical patterns and manipulating the same factors. In the present two studies, we aimed at investigating whether young children would display a global or a local bias in drawing hierarchical patterns and whether this bias would be specific to the constructional nature of the drawing task or would be identical in a perceptual task. Note that it was necessary to use a between-subjects design to prevent practice and priming effects between the drawing and perceptual tasks, yet limiting the comparison between drawing and perception.

The studies that have investigated this question of perceptual processing in typically developing children using perceptual tasks are more numerous than those based on drawing behavior. Most of them have concluded in favor of an initial local processing bias. In a force-choice matching task, Kramer, Ellenberg, Leonard, and Share (1996) asked children from 4 to 12 years of age to express similarity judgments by designating which of two geometrical figures was most like the target hierarchical pattern. Under 7 years of age, children tended to display a local preference bias. In Dukette and Stiles's (1996) study, 4- to 6-year-olds and adults had to select the figure most similar to the target among two possibilities in four different conditions: one in which a global bias was expected, one in which a local bias was induced, and two conditions that did not intend to induce any specific choice because the two choice items presented provided equivalent matches to the global and local levels of the

target. All participants selected global responses, except in the local-induced condition, in which they showed a local bias. When the density of elements in the whole figure was reduced, the 4-year-old children did express more local choices than older children in the two conditions that did not intend to induce any specific choice. These results suggested that young children were capable of processing both levels of organization, though local processing had an initial advantage. Finally, Burack, Enns, Iarocci, and Randolph (2000) showed that age related performance improvements in a visual search task were more important in global than in local processing between 6 and 10 years of age.

However, the reverse finding of an initial global bias has also been revealed in the literature. When children were asked to decide under short exposure times whether two patterns were the same on the basis of the local elements or of the global shape, 6- and 10-year-olds demonstrated a strong global bias, stronger than the one showed by adults (Mondloch, Geldart, Maurer, & de Schonen, 2003). Children were also less accurate on local than on global trials, contrary to adults. At 14 years of age, performance looked adult-like. This developmental pattern suggests a slower improvement with age in local than in global processing. Kimchi, Hadad, Behrmann, and Palmer (2005) demonstrated that both developmental trends were indeed likely to emerge, depending on contextual and task factors, in particular whether local elements in the hierarchical patterns were few large or many small. More recently, Scherf, Behrmann, Kimchi, and Luna (2009) argued that it is the formation of a precise integrated shape representation that would develop until late in adolescence. Finally, Poirel, Mellet, Houdé, and Pineau (2008) showed that a developmental change in preferential processing level occurred early in the first years of life, revealing a clear local preference at 4 years of age, followed by a global preference at 6 years of age.

What the literature makes clear is that many parameters determine whether a local or global bias emerges at the different ages in a perceptual task. In particular, the exposure duration of the patterns seems especially relevant to differences in the findings (Kimchi, 1992). None of the drawing studies carried out with typically developing children has tested the effect of stimulus duration. Yet, several studies have shown that short exposure times facilitated global precedence in adults when the density of local elements was standard (e.g., Kinchla & Wolfe, 1979; Martin, 1979; Navon, 1977; Paquet & Merikle, 1984). We therefore decided to present the hierarchical patterns under short or long exposure durations in both the drawing and perceptual tasks. Furthermore, Navon (1977) tested the interference effects between local and global levels comparing performance when consistent or inconsistent patterns were shown to the participants and revealed global-to-local interference (see also Kimchi, 1988, 1992; Martin, 1979). None of the drawing studies run with typically developing children has compared performance with consistent and inconsistent patterns. Thus, the question is still open as to know whether typically developing children would

manifest possible interference effects in their drawings of inconsistent hierarchical patterns. Finally, Poirel et al. (2008) demonstrated that a change in perceptual bias occurred early, between 4 and 6 years of age. We included children as young as possible in our experiments. Children at 3 years of age are able to draw circles and squares. We built hierarchical patterns using these two shapes and tested children between 3 and 9 years of age.

Drawing hierarchical patterns requires children to process both levels of organization and to integrate one to the other. We focused on these two aspects and not on the accuracy with which each level was reproduced. Accuracy in drawing depends on several factors that do not all relate to how information is encoded (e.g., Miyahara, Piek, & Barrett, 2008; Vinter & Mounoud, 1991). Thus, we performed an analysis based on the categories of drawings made by children at the different ages. Young children seem able to attend to both the global and local levels (Dukette & Stiles, 2001). However, if these levels are introduced in their drawings, we expected that young children would not be able to integrate them but would produce drawings with the local elements and the global shape juxtaposed or combined following other topological relationships. Several drawing studies have indeed revealed convergent findings showing that young children parse compound spatial patterns in independent parts, entertaining simple topological relationships (e.g., Akshoomoff & Stiles, 1995; Picard & Vinter, 1999; Tada & Stiles, 1996; Vinter & Marot, 2007). Thus, young children should draw preferentially isolated elements rather than the global shape. However, consistent patterns should enhance the production of integrated drawings, and short pattern durations should reinforce global processing.

Finally, our sample of children included both girls and boys because boys have been reported to make significantly more global perceptual judgments than girls (Cahill, 2003; Kramer et al., 1996). This finding is consistent with developmental models that suggest an early left-hemisphere advantage for girls and a right hemisphere advantage for boys (Coluccia, Iosue, & Brandimonte, 2007). However, Dukette and Stiles (1996) mentioned exactly the reverse result in 4- to 6-year-olds and in adults in a force-choice matching task, with female participants making more global level matches than male participants. Gender differences were therefore worth investigating.

A. Experiment 1: Drawing hierarchical patterns in children

Method

Participants.

A total of 108 right-handed Caucasian children (55 girls, 53 boys), between 3 and 9 years of age, participated in the experiment. They were divided into seven age groups with age distribution as illustrated in Table 1.

Table 1. *Age distribution of participants in the drawing experiment*

No	Age group	<i>N</i>	<i>M / F</i>	<i>Mean</i>	<i>SD</i>
1	3	15	6 / 9	3.3	0.30
2	4	16	8 / 8	4.6	0.28
3	5	15	7 / 8	5.6	0.31
4	6	15	8 / 7	6.4	0.32
5	7	15	8 / 7	7.5	0.28
6	8	16	8 / 8	8.6	0.27
7	9	16	8 / 8	9.4	0.33
Total		108	53 / 55		

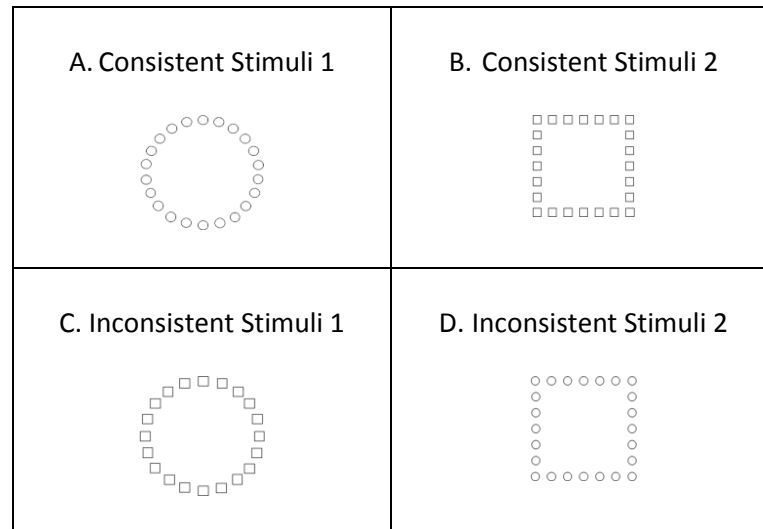
Each age group corresponded to one school level (3- to 5-year-olds: nursery and kindergarten levels). Handedness was assessed by testing children on eight items from Bryden's (1977) test, four unimanual items (drawing, throwing a ball, holding scissors, and brushing teeth), and four bimanual items (closing a bottle, hitting a nail with a hammer, lighting a match, and drying a plate with a tea cloth). Only children who obtained a score above 6 were selected. The handedness test was carried out in a pre-experimental session and completed 1 week before the experiment. None of the children were educationally advanced or retarded, and their vision was normal. Children were largely from middle socioeconomic status families. They were tested individually in a quiet room at their schools. Informed written consent was obtained from parents of each child participating in the study.

Material.

Stimuli were displayed as bitmap files and were presented on a 36-cm - 27-cm computer screen. Four targets were used in the familiarization phase: a big circle or square (diameter/side's length: 4 cm) and a set of five randomly arranged small circles or squares (diameter/side's length: 3 mm); all four targets were traced in a dashed line. The four targets shown in the test were as follows: a square made of small squares (consistent stimulus) or of small circles (inconsistent stimulus), and a circle made of small circles or of small squares. Illustrations of the targets can be seen in Figure 16. The global shape was 4 cm of height and

width. Each small local shape was 3 mm high and 3 mm wide. There were 26 local elements in each larger shape, which corresponded to a standard condition with respect to the density effect (Kimchi, 1988; Martin, 1979). The target appeared centered in the upper half of the monitor screen. The location of the monitor was adjusted so that the viewing distance was at 60 cm. The middle of the screen corresponded to the participant's body midline.

Figure 16. *Illustration of the target hierarchical patterns used in Experiment 1.*



Procedure.

In a short familiarization phase, the children were introduced to the instructions and experimental conditions. They were instructed to copy as accurately as possible the model that appeared on the screen. They were told to concentrate their attention on the screen because the models would stay visible for a very short time on some trials. The experimenter gave them a sheet of paper (A5 format) and a black pencil and asked them to adopt a comfortable and stable posture for drawing. The four familiarization targets appeared for either a long (3-s) or short (300-ms) duration. The order of presentation of the stimuli was randomized. When the model disappeared, the participants were asked to make their drawing without any time constraints. When the drawing was finished, the experimenter took away the sheet of paper, gave a new one to the participants, and waited for their ready-signal before triggering the display of the next model. The children produced eight drawings in the familiarization phase. All children noticed the difference in size of the figures and reproduced a big and a small circle or square.

The procedure was basically the same in the experimental phase. The children were told that they would now see patterns such as a big square or circle made of small squares or circles. The experimenter showed them an example of the patterns to ensure that they were aware of the presence of the two levels of organization. The children were asked to focus

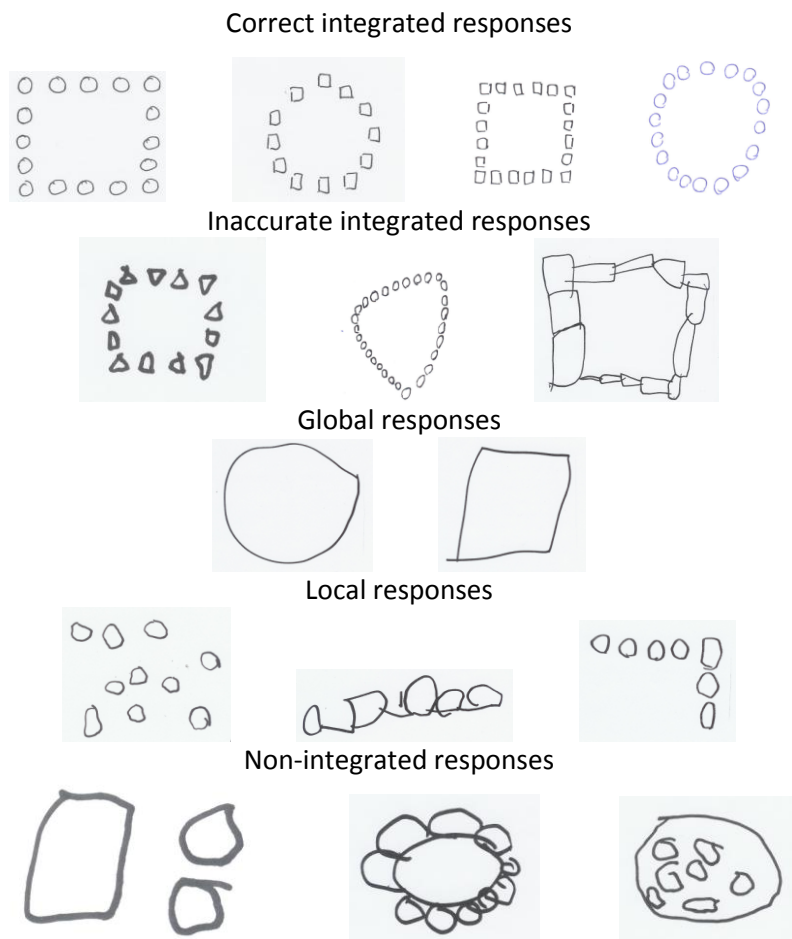
their attention on the monitor screen and to copy the pattern as accurately as possible. They produced a total of 16 drawings (2 consistent and 2 inconsistent patterns X 2 durations X 2 trials). A complete random order was used for the targets' presentation.

Data coding.

The drawings were sorted into five categories, illustrated in Figure 17.

- **Correct integrated response:** The overall global shape as well as the local elements were correctly reproduced (we did not code whether the size or the number of elements or the regularity of the distance between elements or the accuracy of the right angles in the squares were correct).

Figure 17. Illustration of the categories of responses in the drawing task.



- **Inaccurate integrated response:** The drawings comprised a global shape made of small elements (the two levels were present and integrated). However, the global shape was deformed or the local shapes were deformed or both the global and local shapes were

deformed (they were ellipses or rectangles, for instance). Only shape deformations were considered here.

- **Global response:** The overall global shape was reproduced with a continuous line, and the local elements were absent. We did not differentiate the cases in which the shape was deformed (the 3-year-old children were not all able to draw squares correctly).
- **Local response:** A series of small circles or squares was reproduced. The overall global shape was absent. The elements were either isolated or linked one to the other, or they formed a part of the target. The shape of the local elements was not coded. As illustrated in Figure 16, most of the drawings were ambiguous, mixing circles, ellipses, deformed squares, or rectangles.
- **Nonintegrated response:** The local elements were either juxtaposed or superposed to the global shape or nested (the superposed drawings were rare).

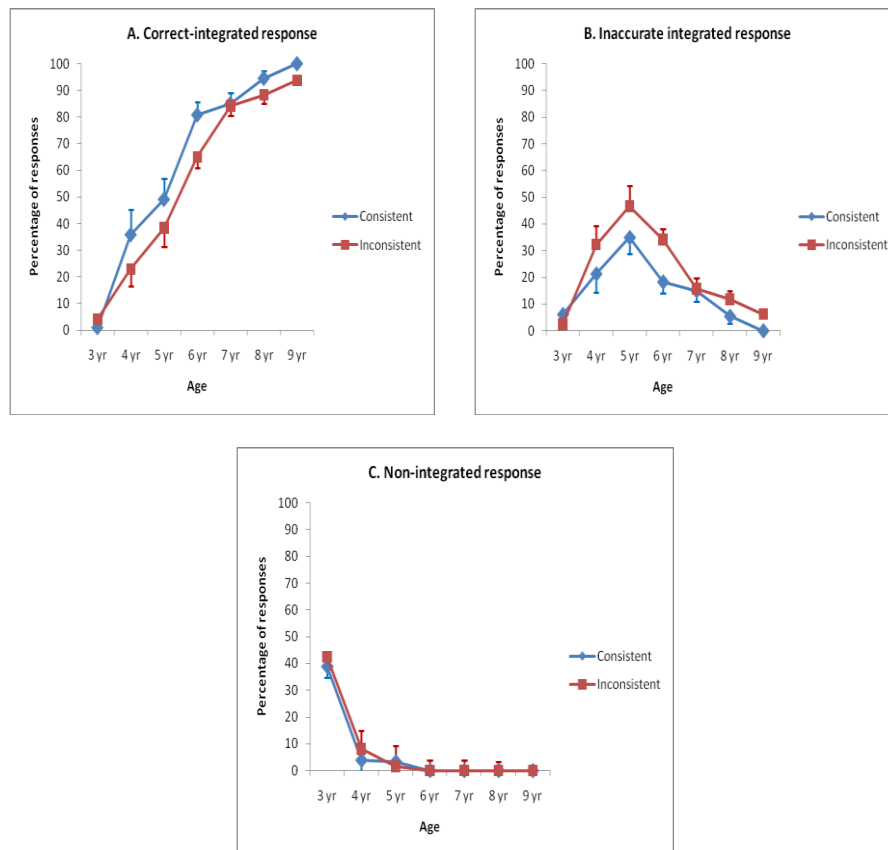
Two judges coded the drawings independently. They were naive to the experimental conditions (type of model shown, duration of exposure) in which each drawing was produced. Their percentage of agreement was 91%. The disagreements were settled by the two judges working together, before data analysis.

The data were analyzed with nonparametric tests because homoscedasticity was not held in most of the cases. The Kruskal–Wallis test (H value) was used to test overall age differences, the Mann–Whitney test (U value) was used to test gender differences or age differences between two groups, and the Wilcoxon signed-rank test (T value) was used to test consistency and duration effects. We followed Neuhaüser and Ruxton's (2009) advice for the use of appropriately rounded mean frequencies prior to the ranking procedure.

Results

Gender did not yield significant differences (all $ps > .10$) and was ignored in the reported analyses. Figure 18 depicts the results as a function of age and consistency for the integrated and nonintegrated responses.

Figure 18. Percentages of responses in the drawing task as a function of age and consistency

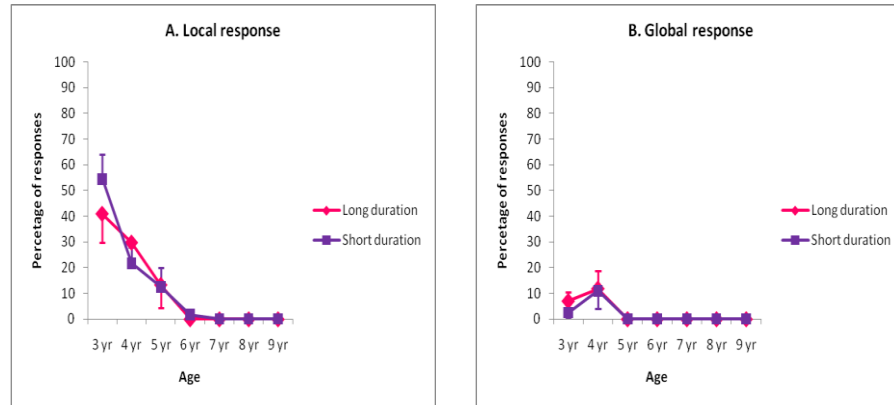


The frequency of *correct integrated* responses varied significantly across the age groups, $H_{(6, N=108)} = 83.8$, $p < .01$, increasing between 3 and 9 years of age. The transitions between 3 and 4 years of age ($U = 36.5$, $n_1 = 15$, $n_2 = 16$), then between 5 and 6 years of age ($U = 40$, $n_1 = n_2 = 15$), and finally between 6 and 9 years of age ($U = 4$, $n_1 = 15$, $n_2 = 16$) were significant (all $ps < .01$). Children produced more frequently correct integrated drawings in response to consistent ($M=64.1\%$, $SD=39.4$) than to inconsistent ($M=56.9\%$, $SD=37.1$) targets, $T_{(N=108)}=406$, $p<.01$. No other significant differences were found (all $ps > .30$). The occurrence of *inaccurate integrated* responses differed across ages, $H_{(6, N = 108)} = 46.3$, $p < .01$, increasing between 3 ($M = 4.3\%$, $SD = 10.9$) and 5 ($M = 40.8\%$, $SD = 23.9$) years of age ($U = 23$, $n_1 = n_2 = 15$, $p < .001$), then diminishing as depicted in Figure 18B. The decrease between 5 and 7 years of age was already significant ($U = 44.5$, $n_1 = n_2 = 15$, $p < .001$). These inaccurate integrated responses were more frequently produced when drawing inconsistent ($M = 21.2\%$, $SD = 23.3$) than consistent ($M = 14.3\%$, $SD = 20.8$) targets, $T_{(N = 108)} = 466$, $p < .01$. No other significant differences were reported. Note that a qualitative analysis of the shape deformations did not reveal any systematic deformations of one level (local or global) as a function of the other (as, e.g., diffusion from the global shape to the local one or vice-versa).

As depicted in Figure 18C, the *nonintegrated* responses dropped out rapidly between 3 and 4 years of age and disappeared at 6 years of age. The differences between the age groups were significant, $H_{(6, N=108)} = 50.5, p < .01$.

Figure 19 reports the results as a function of age and duration for the global and local responses.

Figure 19. *Percentage of responses in the drawing task in Experiment 1 as a function of age and duration*



The *local* responses were seen in almost 50% of the drawings made by the youngest children, and they decreased progressively until 6 years of age, $H_{(6, N=108)} = 62, p < .01$. There were no significant differences because of consistency or duration (all $ps > .40$), but as shown in Figure 19A, the short durations tended to elicit more local responses ($M = 54.4\%$, $SD = 37$) than did the long durations ($M = 40.8\%$, $SD = 43.4$) at 3 years of age, $T_{(N=15)} = 4.5, p = .06$. No other differences were significant (all $ps > .10$). Figure 19B shows that the *global responses* were rare and were produced only by the 3- to 4-year-olds (8% on average), $H_{(6, N=108)} = 18, p < .01$. There were no other significant effects (all $ps > .10$).

Dukette and Stiles (2001) and Lange-Küttner (2000) also studied the integration of local and global information in children's drawing. Our results are similar to those of Dukette and Stiles in that from 4 years of age, children incorporated both local and global elements into their drawings. On the other hand, Lange-Küttner found that 5-year-olds often drew using only the global elements of the stimulus. We never observed the use of only global elements at any of age, and Dukette and Stiles did not report only global elements in drawings in their study.

In the current study, if children used only a single dimension, it was invariably the local dimension. These unidimensional responses were seen primarily at 3 years of age, were rare at 4 years of age, and completely disappeared between 5 and 6 years of age. In our study, the integrated responses, either correct or inaccurate, developed rapidly between 3 and 5 years

of age. At 6 years of age, children produced correct integrated responses in more than 70% of the cases, and these responses characterized almost 100% of the drawing production at 9 years of age. Would the developmental trajectory shown in this drawing experiment be revealed in a perceptual task? The perceptual task used in Experiment 2 was based on patterns' similarity judgments.

B. Experiment 2: Perceptual similarity judgments of hierarchical patterns in children

The results of Experiment 1 suggest that local processing dominated first and that local and global processing started to be integrated at 5 years of age. Would a similarity judgment task show that global processing preference emerged somewhere around 5 years of age? We designed the similarity judgment task so that it was as similar as possible to the drawing task. The same consistent or inconsistent target patterns that were used in Experiment 1 were shown to children in Experiment 2 under the same exposure duration conditions. Children had to decide which figure, among four choices, was the most similar to the target. Following Poirel et al. (2008) and our findings in Experiment 1, we expected to observe a local bias in the choices made by the youngest children, which should be stronger under long than short target exposure durations. The results of Experiment 1 suggest that this local bias decreased in strength rapidly between 3 and 5 years of age. Dukette and Stiles (1996) reported a preference for global responses from 4 years of age. We expected the transition between local and global preference processing to be located somewhere between 4 and 5 years of age. As we have seen in Experiment 1 that consistent targets enhanced the integration between local and global processing in young children, the preference for global responses should be reinforced by pattern consistency.

Method

Participants.

A total of 224 right-handed Caucasian children (112 girls, 112 boys), between 3 and 9 years of age, participated in the experiment. They were divided into seven age groups of 32 children each, half female and half male as described in Table 2.

Table 2. *Age distribution of participants in the perceptual similarity judgment task*

No	Age group	<i>N</i>	<i>M / F</i>	<i>Mean</i>	<i>SD</i>
1	3	32	16 / 16	3.5	0.29
2	4	32	16 / 16	4.6	0.27
3	5	32	16 / 16	5.5	0.27
4	6	32	16 / 16	6.6	0.30
5	7	32	16 / 16	7.5	0.28
6	8	32	16 / 16	8.4	0.29
7	9	32	16 / 16	9.5	0.30
Total		224	112 / 112		

The criteria used to select the children were exactly the same as those described in Experiment 1. Participants in Experiment 2 were not in Experiment 1.

Material.





As in Experiment 1, the stimuli were displayed as bitmap files and were presented on a 36-cm x 27-cm computer screen. Two targets were shown in the familiarization phase: a circle and a square (diameter/side's length: 4 cm), traced in a continuous line. The same stimuli traced in a dashed line, together with a cross and a star (same size, traced in a dashed line), were used for the responses' choices. When the circle (or square) was presented, for instance, a dashed circle (or square), a dashed square (or circle), the cross, and the star were the choices.

The four targets shown in test were exactly the same as those used in Experiment 1. The responses' choices included a square, a circle— both traced in a continuous line (height/width of 4 cm)—a set of seven small squares (3 mm), and a set of seven small circles (3 mm), traced in a continuous line and randomly arranged within a virtual 4-cm x 4-cm frame. Pilot testing showed that several local elements randomly displayed were a much more efficient stimulus than only two or three local elements. We used seven elements because we observed that young children drew on average seven elements in Experiment 1 when they produced local responses. The target appeared centered in the upper half of the screen, and the four responses appeared below the target, centered in the lower half. The location of the computer monitor was adjusted so that the viewing distance was at 60 cm, and the middle of the screen corresponded to the participant's body midline.

Procedure.

During the initial phase children were familiarized to the material and the instructions. They were presented with a target stimulus (circle or square) and were asked to select, among four choices (see Figure 20), the stimulus that was the most similar to the target.

Figure 20. Example of choices in perceptual similarity judgment task for experiment 1

 <p><u>Global response or Erroneous global response</u></p> <ul style="list-style-type: none"> • if the target is a pattern with a big square as a global shape, then the choice is considered as global response • if the target is a pattern with small squares as local elements, then this choice is considered as erroneous global response 	 <p><u>Global response or Erroneous global response</u></p> <ul style="list-style-type: none"> • if the target is a pattern with a big circle as a global shape, then the choice is considered as global response • if the target is a pattern with small circles as local elements, then this choice is considered as erroneous global response 	 <p><u>Local Response or Erroneous local response</u></p> <ul style="list-style-type: none"> • if the target is a pattern with small circle as local elements, then the choice is considered as local response • if the target is a pattern with other than small circles as local elements (eg. big circle or big square, or small squares), then this choice is considered as erroneous local response 	 <p><u>Local Response or Erroneous local response</u></p> <ul style="list-style-type: none"> • if the target is a pattern with small squares as local elements, then the choice is considered as local response • if the target is a pattern with other than small squares as local elements (eg. big square, big circle or small circles), then this choice is considered as erroneous local response
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The experimenter told the participants to focus their attention to the screen because the target would appear for a very short time in some cases. This phase included four trials (circle or square, presented in the two durations), and it was repeated once when children selected the wrong choices. The target remained visible for 3 s or for 300 ms, followed by an 800-ms blank screen, which was followed by the four choices. Children used a mouse to select the stimulus they considered most similar to the target, with children who were unable to use the mouse using their index finger to indicate their choice. In this last case, the experimenter clicked on the choice that the child has pointed to. The participants were asked to keep their position constant throughout the experiment. The experimenter checked the participant's position before triggering the next trial. Most children 3 years of age and some of the 4-year-olds needed a repetition of the familiarization phase.

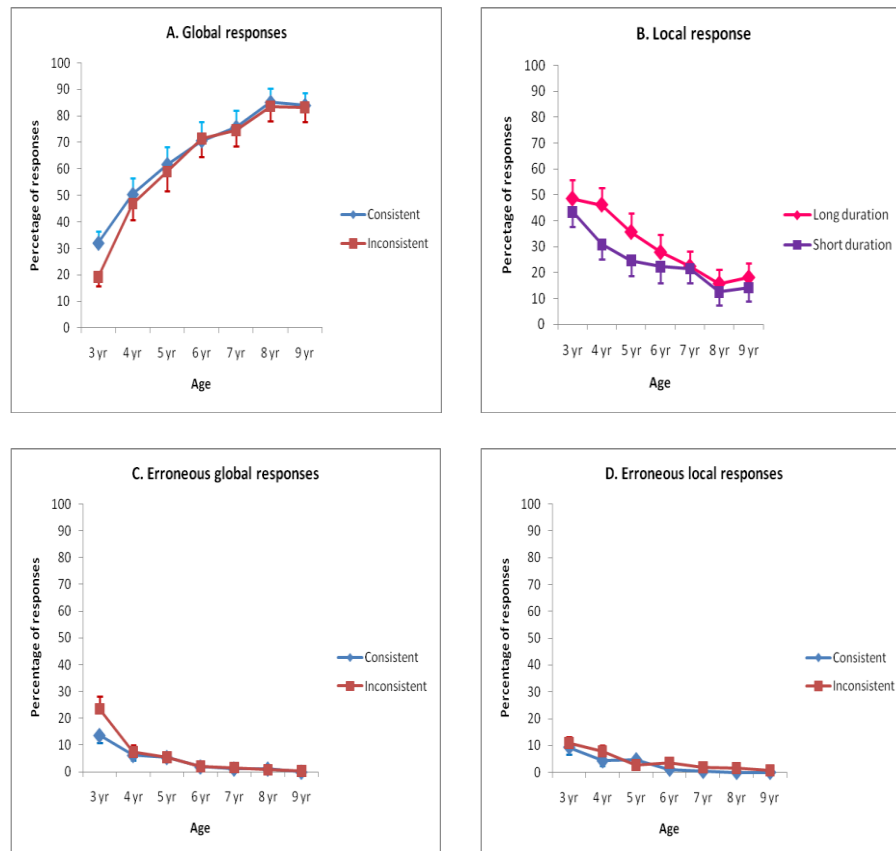
The instructions given in the test phase were identical to those in the familiarization phase. Four targets were shown in the test phase: Two were consistent stimuli (circle made of small circles or square made of small squares), and two were inconsistent stimuli (circle made of small squares or square made of small circles). They were displayed either for 3 s (long duration) or for 300 ms (short duration), and the four choices appeared after a blank screen of 800 ms and remained visible on the screen until the children selected one response. The experimenter waited for the participants' ready signal before triggering the next trial. Each target was presented twice at each duration. The targets as well as the durations were randomized across the 16 trials. Four choices were presented to the participants: a circle, a square, a set of small circles, and a set of small squares. One corresponded to a global response (e.g., choice for the square when a square made of circles or squares was shown), one was a local response (e.g., choice for the set of squares when a square made of squares or a circle made of squares was presented), one was an erroneous global response (e.g., selection of the circle when the square made of squares or circles was displayed), and one was an

erroneous local response (e.g., choice for the set of circles in response to a square or a circle made of small squares). In the case of inconsistent targets, the erroneous global responses could reveal diffusion from the local to the global level, and the erroneous local responses could reveal diffusion from the global to the local level. They were simply false responses in the case of consistent targets. The location of the four responses was randomized.

Results

Figure 21 depicts the frequencies of global, erroneous global and erroneous local responses as a function of age and consistency, and of local responses as a function of age and duration.

Figure 21. *Percentage of responses in the similarity judgment task in Experiment 2 as a function of age and consistency (A = global responses, C = erroneous global responses, D = erroneous local responses) or a function of age and duration (B = local responses)*



The proportions of *global responses* (see Figure 21A) differed significantly across ages, $H_{(6, N = 224)} = 62.3, p < .01$, with a rapid increase located between 3 and 5 years of age ($U = 268, n_1 = n_2 = 32, p < .01$). The consistent targets elicited more global responses ($M = 65.7\%, SD = 37.6$) than did the inconsistent ones ($M = 62.5\%, SD = 41.5$), $T_{(N = 224)} = 1,214, p$

< .05. It was only at 3 years of age that significant differences related to consistency were observed, $T_{(N = 32)} = 20$, $p < .01$. No other differences were significant, whether duration or gender was concerned (all $ps > .20$). Figure 21B shows that the *local responses* decreased progressively with age, with the 3-year-olds selecting them in 46% of the cases and the oldest children selecting them in 16% of the cases. The differences between ages were significant, $H_{(6, N = 224)} = 35.7$, $p < .01$. These responses were more frequent when the targets remained visible for long ($M = 35.5\%$, $SD = 41$) rather than short ($M = 24.2\%$, $SD = 34.1$) durations, $T_{(N = 224)} = 1,127$, $p < .01$. This effect of duration was significant at all ages between 3 and 6 years of age (all $ps < .05$). There were no significant differences as regards to consistency or to gender (all $ps > .40$).

As shown by Figure 21C, the choice for *erroneous global responses* differed significantly between the age groups, $H_{(6, N = 224)} = 56.8$, $p < .01$, being observed essentially at 3 years of age. These responses were also less frequent when the duration was long ($M = 3.7\%$, $SD = 11.9$) rather than short ($M = 6.5\%$, $SD = 13.6$), $T_{(N = 224)} = 449$, $p < .01$. Finally, the choice for *erroneous local responses* also differed significantly along ages, $H_{(6, N = 224)} = 45.9$, $p < .01$, decreasing progressively with age. On average, the inconsistent targets ($M = 4.2\%$, $SD = 8.7$) elicited more erroneous local responses than the consistent targets ($M = 2.8\%$, $SD = 8.6$), $T_{(N = 224)} = 502$, $p < .05$, as well as the short durations ($M = 4.9\%$, $SD = 10.7$) in comparison with the long ones ($M = 2.1\%$, $SD = 7.6$), $T_{(N = 224)} = 428$, $p < .01$. Again, we failed to find significant gender differences (all $ps > .10$).

The errors produced by the 3-year-olds are worth focusing. These children pointed significantly more often to the erroneous global responses for the inconsistent targets ($M = 23.4\%$, $SD = 27.2$) than for the consistent ones ($M = 13.6\%$, $SD = 16.6$), $T_{(N = 32)} = 48$, $p < .05$. The occurrence of erroneous global responses for the inconsistent targets was also significantly higher than the frequency of the other error types, whether the erroneous local responses associated to the inconsistent patterns ($M = 10.9\%$, $SD = 12.2$), $T_{(N = 32)} = 89$, $p < .05$, or whether the erroneous local responses associated to the consistent targets ($M = 9.3\%$, $SD = 15$), $T_{(N = 32)} = 84$, $p < .05$, were concerned. Thus, the inconsistent targets provoked specifically the production of erroneous global responses in the 3-year-old children.

In summary, the results show that when children had to decide whether a compound figure bore more similarity with its global shape or with an arrangement made of its local elements, they tended to select more and more often the global shape and less and less often the local elements as age progressed. At 3 years of age, the local responses dominated over the global responses, $T_{(N = 32)} = 152$, $p < .05$. At 4 years of age, no significant differences appeared between these responses, $T_{(N = 32)} = 216$, $p > .30$, and at 5 years of age, the global responses were selected twice as often than the local responses, $T_{(N = 32)} = 144$, $p < .05$. The choice for the global responses was facilitated by pattern consistency at 3 years of age. The

local responses were more frequent when the targets remained visible for longer durations in the children less than 7 years of age. Erroneous responses were rare, except at 3 years of age. At this age, the erroneous global responses were largely the most frequent errors, and they occurred significantly more often with inconsistent figures. This result is important because it reveals a phenomenon of diffusion from the local to the global level. Finally, like in the drawing experiment, no significant gender differences emerged in the present experiment. This finding corroborates the results reported in a recent study in which no gender differences in perceptual processing biases were found (Scherf et al., 2009).

Discussion

The aim of the present studies was to investigate the development of children's spatial analysis of hierarchical patterns in a constructional and a perceptual task. The similarity judgment task revealed at which age local or global preferences emerged, and the drawing task, with its additional requirements in planning and motor demands (van Sommers, 1989), showed to what extent children were able to integrate a global and local analysis of the patterns. Two main findings emerged from these experiments. First, there were clear qualitative changes in the course of development in the relationships between the global and local modes of processing. Second, children's performance was sensitive to both pattern's consistency and target's exposure time in the two tasks.

A. Qualitative Changes in the Relationships Between the Local and Global Modes of Processing

The results are congruent with regard to the type of processing that dominated at the youngest age. When the 3-year-olds were asked to draw the compound models, they reproduced only local elements in 50% of the cases. It was with approximately the same frequency that they selected the local responses in the similarity judgment task. These findings support the view that the local bias in drawing was not due to the constructional nature of the task (Porter & Coltheart, 2006), though evidence obtained with a within-subjects design would be still more convincing. They also confirm that local processing dominates the global one in young children (Dukette & Stiles, 1996; Kramer et al., 1996; Poirel et al., 2008). This could be related to differential rates of development between the left and right hemispheres (Molfese & Segalowitz, 1988), to reduced oculomotor exploration involving incomplete processing of visual scenes (Kowler & Martins, 1982; Poirel et al., 2008), or to attentional functioning in young children who put more attention to parts than to the whole (Tada & Stiles, 1996). The extent to which top-down processes, such as identification or

naming processes (Poirel et al., 2008), were involved was not clear in our task, as young children might have a tendency to name the most numerous elements (thus, the local elements).

However, the drawing task showed that even at 3 years of age children were capable to attend to both levels of pattern organization, as shown by Dukette and Stiles (2001) in the 4-year-olds. In around 40% of the cases, the 3-year-old children produced drawings in which both levels were present, but these were either juxtaposed or superimposed or nested. Tada and Stiles (1996) reported similar results in the copying of compound figures. Likewise, Vinter and Marot (2007) mentioned that young children tended to copy stairs-like patterns (made of embedded rectangles) as a series of independent and juxtaposed rectangles. Thus, at 3 years of age, children were capable of perceiving both the local and global organization of compound patterns, but these modes of spatial information processing operated independently, as if they did not refer to a unique entity. If we assume that global processing tends to rely on the right hemisphere and local processing on the left hemisphere (e.g., Moses et al., 2002), this independent functioning may be a consequence of the still immature interhemispheric communication in the integration of visual information. It is indeed only at around 2 years of age that processing between the two hemispheres starts to be coordinated (Liegeois, Bentejac, & de Schonen, 2000). However, other accounts for the nonintegrated drawings can be proposed. They may denote the difficulties encountered by young children when they have to combine basic geometrical shapes in their drawings (Freeman, 1980). The nonintegrated drawings can also reveal the difficulties encountered by young children in the understanding of parts-whole relationships, as shown in drawing studies (Picard & Vinter, 2007; Tada & Stiles, 1996; Vinter, 1999; Vinter & Marot, 2007) or in cognitive tasks (e.g., Inhelder & Piaget, 1964).

Important changes occurred after 3 years of age. The nonintegrated responses dropped abruptly between 3 and 4 years of age, whereas the production of integrated responses, whether correct or inaccurate, increased significantly. Whereas the 3-year-olds either considered only one component of the target (the local one) or one component at a time (nonintegrated responses), the 4-year-olds started to process the two components together. A second developmental change occurred between 4 and 5–6 years of age. It was indeed from 5 to 6 years of age onwards that children produced correct integrated responses more frequently than local responses. The global bias in drawing, as reported by Lange-Küttner (2000), was not observed at all in our own drawing study. Children at this age clearly attended to both levels of organization, and they were able to successfully plan their drawing behavior, integrating accurately the two components. No further qualitative change occurred, but a progressive performance refinement was shown between 6 and 9 years of age.

Congruent with this developmental sequence, the local bias shown in the perceptual task in the youngest children disappeared when both levels of organization started to be integrated. A global processing preference emerged at 5 years of age in this perceptual task. This evolution with age found in the similarity judgment task appeared in line with previous findings, though some divergences were worth pointing out. The local bias lasted until 5 years of age in Poirel et al.'s (2008) study, until 6 years of age in Kramer et al.'s (1996) study, and was obtained only under low elements density in Dukette and Stiles's (1996) study. It was obtained under normal elements' density conditions and disappeared between 4 and 5 years of age in our study. However, none of these studies used the same experimental conditions. Note that the global processing preference as measured by similarity judgments does not mean that children process the global shape first and then the local elements. Other types of tasks are needed to trace the time course of each process. Using appropriate tasks, Scherf et al. (2009) have indeed shown that it is only late into adolescence that evidence of global precedence can be found. This perceptual global bias means that children are more likely to base their similarity judgments between two patterns on their global shapes than on their local elements, these two levels of organization being perfectly attended to, as shown by the drawing task.

B. Sensitivity to Pattern Consistency and Target's Exposure Time

As could be expected, correct integrated drawings were facilitated by consistent patterns as well as the choice at young ages for global responses in the similarity judgment task. More important, the most frequent errors in the perceptual task were the erroneous global responses made by the 3-year-olds in the face of inconsistent patterns. Adults were shown to be subject to interference effects revealing diffusion from the global (dominant level) to the local level in the face of inconsistent patterns (Kimchi, 1988; Martin, 1979; Navon, 1977). Our results suggest that a similar but reversed effect occurred at 3 years of age: Children's errors revealed diffusion from the local (dominant level) to the global level. To our knowledge, this is the first time in the literature that this effect is reported in young children. It should be further investigated, adapting the methods used with adults to these young children. Interestingly, insofar as erroneous local responses to inconsistent targets revealed global to local diffusion, this effect emerged only on average across ages, congruent with the fact that on average, global processing dominated over local processing.

In the case of drawing, pattern consistency had an impact on the integrated responses, not on the local or global responses. The inconsistent patterns elicited an increase of inaccurate integrated drawings. If we assume that these patterns required more effortful

processing, interference effects between local and global processing could be enhanced by these patterns, leading to less accurate reproduction of each level.

The results obtained from the manipulation of exposure times in the similarity judgment task are informative. The choice for local responses was more frequent with long than with short durations. In adults, Kimchi (1998) demonstrated that the global configuration of patterns made of many relatively small elements was primed at short exposures, whereas the local elements were primed at longer durations. The converse pattern of results was shown with configurations made of few, relatively large elements. She suggested that grouping many relatively small elements relies on rapid and effortless processes, whereas the individuation of many small elements would occur later and would be attention demanding (see also Kimchi et al., 2005). In line with this theory, long durations should make it possible to select local responses. This is exactly what we observed in Experiment 2 in the 3- to 6-year-olds, that is, until global processing preference was clearly established.

In the drawing experiment, exposure times had only a marginally significant impact. Drawing local elements tended to be more frequent after short than long durations in the 3-year-olds. This effect was in opposition with the one obtained in the perceptual experiment, but it was only marginal, making its interpretation uncertain. Further studies investigating specifically the role of exposure times in drawing hierarchical patterns are needed to make this issue clearer.

CHAPTER 3. Children's Spatial Analysis of Simple and Complex Hierarchical Patterns in a Drawing and Similarity Judgment Task

Introduction

The aim of the two studies reported in chapter 3 is to investigate how children perceive and draw simple and complex hierarchical patterns. Such comparison between simple and complex patterns has yet not been studied in the literature. It is important to note that the present two experiments are clearly exploratory, due to the lack of corresponding studies in the literature.

The geometrical forms designed for these experiments were estimated to be appropriate to the age of the children. However, because of the complex figures, children as young as 3 years of age were not able to participate in the experiments. Thus, the youngest age group included in the present studies was 4 years old. At 4 years of age, children are more familiar with geometrical forms than letters or numbers. The use of geometrical forms in the study of global and local processing has been initiated in the study of Kimchi & Palmer (1982), and since, a lot of researches have employed geometrical forms as we also did in the two previous experiments (Navon, 1983, Kimchi, 1988; Love et al.,1999).

Simple and complex geometrical forms were contrasted because Tada & Stiles (1996) showed that the youngest children segmented out simple, well-formed, spatially independent parts and used simple relational structures to bind these parts together. As they got older, children constructed forms that included increasingly complex parts and relations. This result agrees with those which propose that younger children process the local elements before the global shape. We expected that, in the drawing task, the younger children should produce more non-integrated responses to the complex pattern than to the simple ones. They should be more inclined to reproduce the parts of the patterns than the frame. In the similarity judgment task, the younger children should select more local responses for the complex figures than for the simple ones.

A. Experiment 3: Drawing simple and complex hierarchical patterns in children 4-10 years of age

Method

Participants.

One-hundred-twenty one children (62 girls), aged between 4 and 10 years, participated in the experiment. They were divided into 6 age groups (see table 3). Each age

group corresponded to one school level (4-5-year-olds: nursery and kindergarten levels). Their vision was normal or corrected to normal and none of these children were educationally advanced or retarded. Children essentially come from families with middle socioeconomic status. They were all monolingual French-native speakers. They were observed individually in a quiet room at their schools. Informed written consent was obtained from parents of each child participating in the study.

Table 3. *Age distribution of participants in Experiment 3*

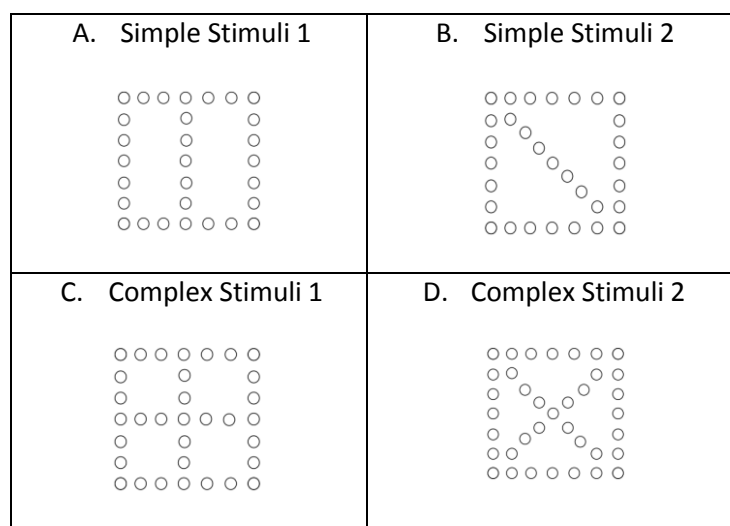
No	Age group	N	M / F	Mean	Range
1	4	20	10 / 10	4.5	3 yr 11 mo-4 yr 9 mo
2	5	21	10 / 11	5.3	4 yr 9 mo-5 yr 9 mo
3	6	20	10 / 10	6.5	6 yr 0 mo-6 yr 9 mo
4	7	20	10 / 10	7.4	6 yr 11 mo-7 yr 9 mo
5	8	20	10 / 10	8.3	7 yr 10 mo-8 yr 8 mo
6	10	20	10 / 10	10.5	9 yr 11 mo-10 yr 10 mo
Total		121	60 / 61		

Material.

Stimuli were displayed as bitmap files and were presented on a 36 cm x 27 cm PC screen. Four targets were used in the familiarization phase: a big circle or square (diameter/side's length: 4 cm). A set of 5 small circles or squares, randomly arranged (diameter/side's length: 0,3 cm), traced in dashed line.

The four targets in the experiment were: a square divided into 2 rectangles or into 2 triangles (figures with simple internal parts, hereafter called "simple figures"), or into 4 squares or into 4 triangles (figures with complex internal parts, hereafter called "complex figures") as shown in Figure 22.

Figure 22. *Illustration of the target hierarchical patterns used in Experiment 3*



The global shape's height and width were 4 cm. Each small local shape's height and width were 0.3 cm. There were 26 local elements in each larger, global level shape, which corresponded to a standard condition with respect to the density effect (Kimchi, 1988; Martin, 1979; Navon, 1983). The target appeared centered on the top of a monitor screen. The location of the PC monitor was adjusted so that the viewing distance was 60 cm, and the middle of the screen corresponded to the participant's body midline. The visual angle for the global shape was 11° and the visual angle for the local shape was 0.87° .

Procedure.

In a short familiarization phase, the children were introduced to the instructions and experimental conditions. They were instructed "to copy as accurately as possible the model which appeared on the screen". They were told to concentrate their attention on the screen, because the models to copy would stay visible for a very short time on some trials. The experimenter gave them a sheet of paper (half of A4 format) and a black pencil, and asked them to adopt a comfortable and stable posture for drawing. Four familiarization targets appeared, either with a long (3 sec) or a short duration (300 msec). The order between these stimuli was randomized. When the model disappeared, the participants were asked to make their drawing, without any time constraints. When the drawing was finished, the experimenter took away the response sheet of paper, gave a new one to the participants, and waited for their ready-signal before launching the appearance of the next model. The children produced 8 drawings in this familiarization phase. All children noticed the difference in size of the figures and reproduced a big and a small circle or square (though the square shape was often deformed by the youngest children).

The procedure was basically the same for the experimental phase. The children were told that they would now see patterns like a big shape made of small shapes. The experimenter showed them an example of these patterns, to ensure that they were aware of the presence of the two levels in the patterns. They were asked to focus their attention on the monitor screen and to copy the pattern as accurately as possible. Every child received 2 trials with each pattern in 2 durations, so in overall, each child produced 16 drawings (4 targets x 2 durations x 2 trials). The order of presentation of these trials was randomized.








Data Coding.

A close inspection of the entire set of drawings showed that a double coding of the data was necessary: a coding of the reproduction of the frame/parts of the targets on the one hand and a coding of the presence/absence of the local elements or global shape on the other hand. The first data coding will be mentioned as frame-part analysis and the second data coding will be mentioned as categorization analysis. The two codings were introduced to get

a more comprehensive view on children's ability to integrate spatial information into their drawing ability.

The coding of the reproduction of the frame/parts structure necessitated 7 categories, with examples depicted in Figure 23.





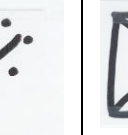
Figure 23. Illustration of the types of responses coded in the frame/parts analysis

Frame Correct	Part Correct	Frame Incorrect	Part Incorrect	Frame Absent	Part Absent	Partial Response
Ex. 	Ex. 	Ex. 	Ex. 	Ex. 	Ex. 	Ex. 

- **Frame correct** : the frame was correctly reproduced
- **Part correct**: the parts were correctly drawn
- **Frame incorrect**: the frame was wrong or the shape was deformed. For instance, a circle was reproduced instead of a square.
- **Part incorrect** : the parts were not correct or the shape was deformed. For instance, the internal diagonal inside the simple target pattern was reproduced as a vertical or the internal “×” parts inside the complex target pattern was reproduced as a “+”.
- **Frame absent**: the frame was not present in the drawing (only the part was reproduced).
- **Part absent** : the parts were absent (only the frame was reproduced).
- **Partial response** : only a part of the frame was drawn (partial frame), the internal parts were partially reproduced (partial response). For instance, the internal “×” part inside a complex pattern target was reproduced as a unique diagonal.

The second type of coding (categorization analysis) was largely inspired by the drawing experiment reported in chapter 2; only one category of drawing was new. There were thus 5 categories as illustrated in Figure 24.

Figure 24. Illustration of the types of responses categorized in drawing simple and complex hierarchical patterns

Correct Integrated Response	Non-Integrated Response	Combined Response	Global Response	Local Response
Ex. 	Ex. 	Ex. 	Ex. 	Ex. 

- ***Correct integrated response:*** the global shape as well as the local elements was reproduced. The precise shape of the global or local structure was sometimes inaccurately reproduced, above all when data from young children were analyzed.
- ***Non-integrated response:*** the local elements were either juxtaposed or superposed to the global shape, or included into it.
- ***Global response:*** the global shape was reproduced with a continuous line, more or less accurately, the local elements are absent.
- ***Local response:*** a series of small circles was reproduced on a line or on two lines connected by a more or less right angle or as agglomerates. The elements were either isolated or juxtaposed one to the other.
- ***Combined response:*** this category did not appear in Experiment 1 and 2. The frame was reproduced in a continuous line, without the local elements while the local elements were drawn for the internal parts or vice-versa as depicted in Figure 24.

Results

Non-parametric tests were used for data analysis because the assumption on normal distribution and homoskedasticity was not met in most of the cases, although the data set was large. The Kruskal-Wallis test (H value) was applied to test overall age differences, the Mann-Whitney test (U value) to test age and sex differences between two groups and the Wilcoxon signed-rank test (T value) to test differences in the complexity of the pattern and duration. The frame-part analysis will be reported before the categorization analysis.

1. Results of the frame-part analysis of drawing

Figure 25 depicted the results as the function of age for the simple and complex stimuli. A significant effect of age for the production of *frame correct responses* was found in this study ($H_{(5, N=121)} = 63.31, p < .01$). The frame correct responses increased significantly rapidly between 4 and 5 years of age ($U=69, n_1=20; n_2=21, p < .01$) as described in Figure 25A and then seemed stable after the age of 5 years. No significant effect of complexity was found for the frame correct responses (all $ps > .05$).

Figure 25. Percentages of responses in the frame-part analysis as a function of age for the simple and complex hierarchical patterns.

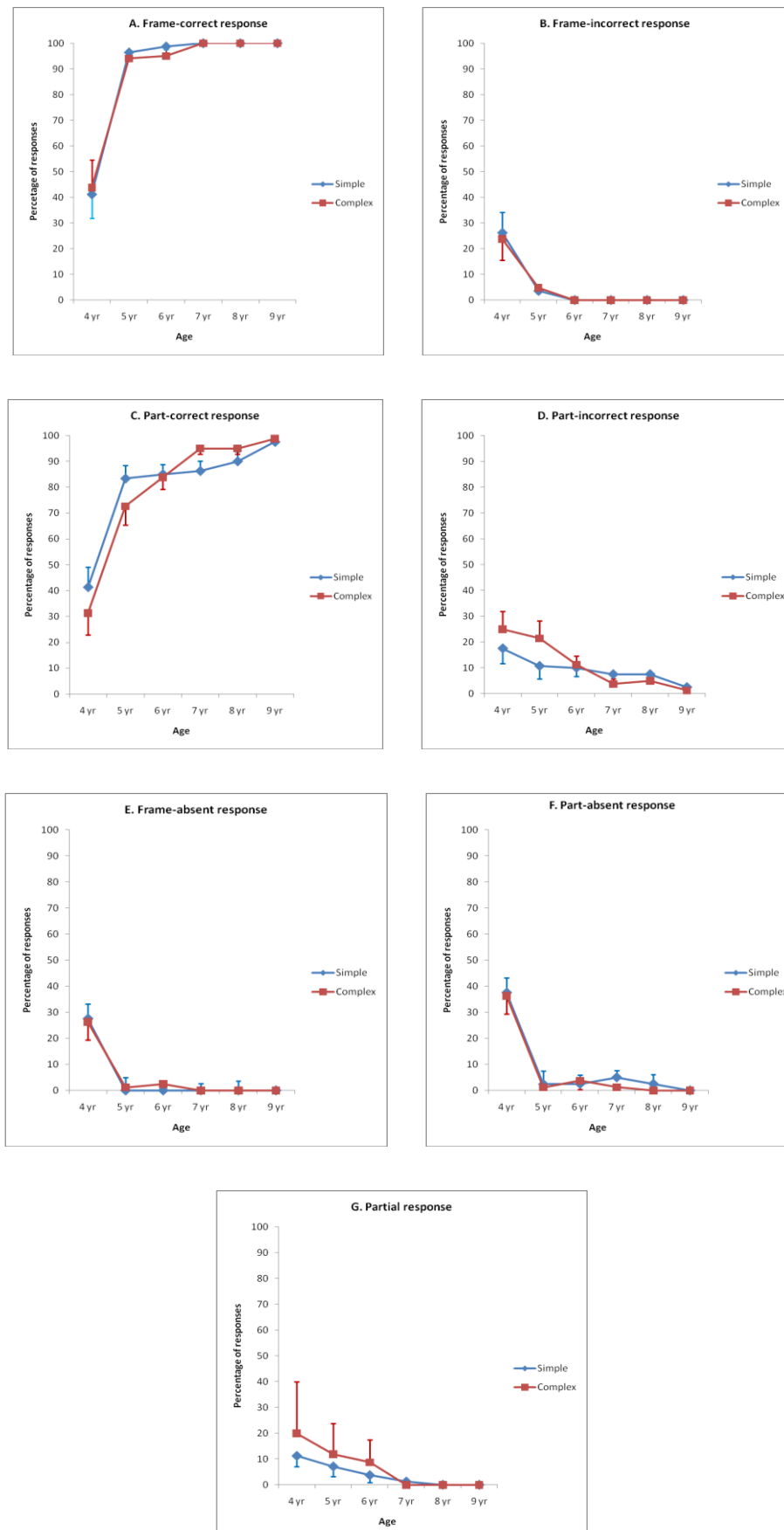


Figure 25B represents the *frame incorrect responses*, which evolved significantly with age, ($H_{(5, N=121)} = 45.75, p < .01$). A significant decline was observed between 4 and 5 years of age ($U=127.5, n_1=20; n_2=21$), $p < .05$, and none of the children gave frame incorrect responses after 6 years of age. No effect of complexity was found in all ages (all $ps > .05$).

The age evolution for the *part correct responses* was significant, $H_{(5, N=121)} = 49.83, p < .01$ as depicted in Figure 25C. A significant transition was also found between 4 and 5 years of age ($U=71, n_1=20; n_2=21$), $p < .01$, the part correct responses increasing abruptly between the two ages. The simple patterns elicited more part correct responses (62.80%) than the complex ones (52.4%) at 4-5 years of age, $T_{(N=41)} = 49.5, p < .05$, while the reverse tended to occur at 7-8 years of age, $T_{(N=40)} = 70, p = .06$.

A significant effect of age was also found in the production of *part incorrect responses* as described in Figure 25D, $H_{(5, N=121)} = 18.88, p < .01$. The part incorrect responses decreased as age increased. A significant transition emerged between 4 and 7 years of age ($U=112.5, n_1=n_2=20$), $p < .01$. The complex patterns tended to elicit more part incorrect responses than the simple ones at 4-5 years of age, $T_{(N=41)} = 71.5, p = .07$.

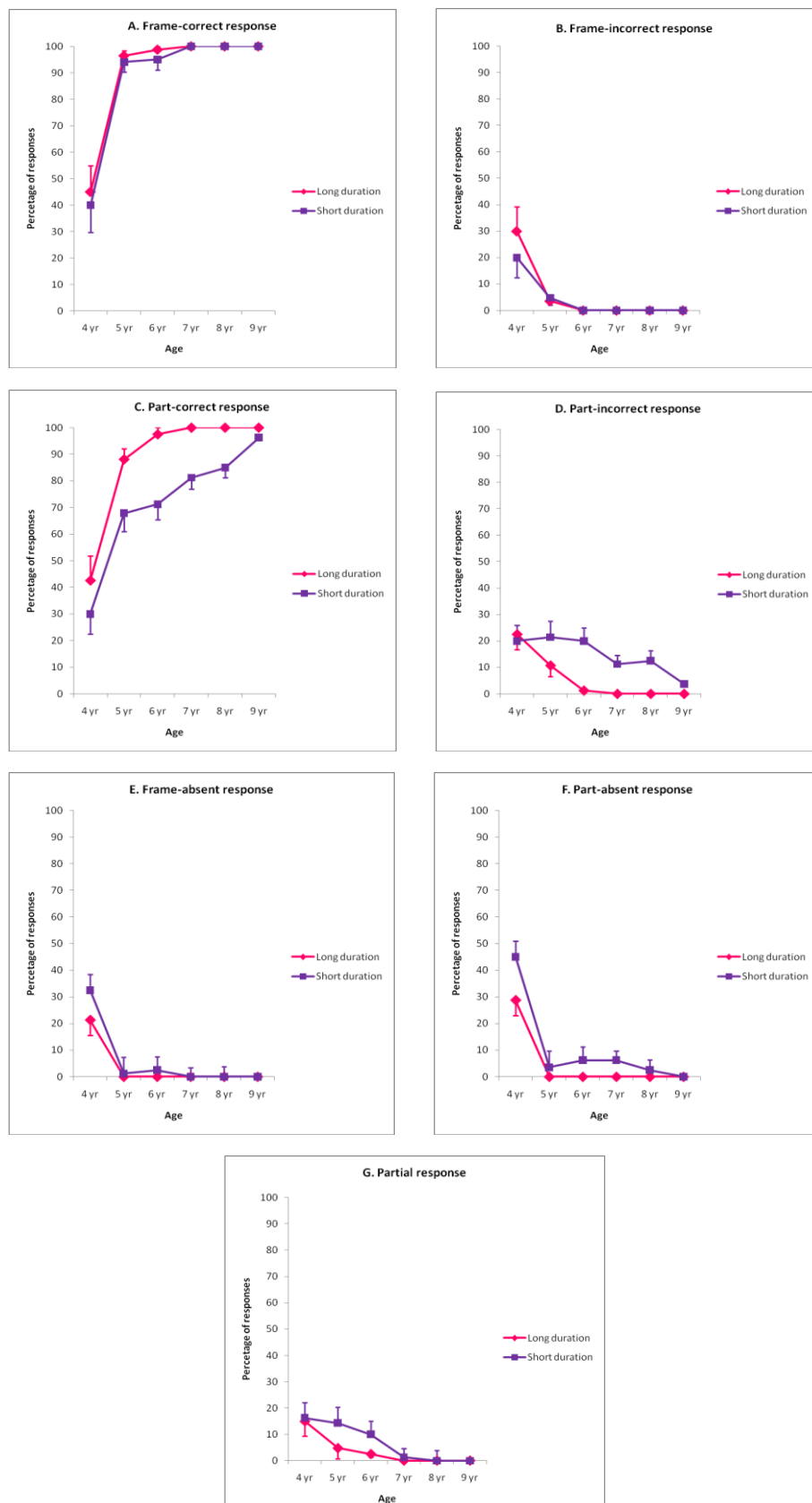
Figure 25E depicted the results for the *frame absent responses* and it also showed a significant decrease of these responses when age increased, $H_{(5, N=121)} = 44.06, p < .01$. The significant transition was found between 4 and 5 years of age, ($U=111.5, n_1=20; n_2=21$), $p < .05$, and there was no significant effect of complexity (all $ps > .10$).

Figure 25F depicted the results for the *part absent responses*. The figure showed a radical decline between 4 and 5 years of age, $H_{(5, N=121)} = 40.34, p < .01$. These responses decreased progressively from 4 years to 5 years of age, ($U=76.5, n_1=20; n_2=21$), $p < .01$, and remained at a low level in children at older ages. No effect of complexity was reported (all $ps > .10$).

The *partial responses*, illustrated in Figure 25G, were rare in each age group, but the slight decline of the responses as age increased still showed a significant effect, $H_{(5, N=121)} = 33.71, p < .01$. An effect of complexity was found between 4 and 6 years of age, $T_{(N=61)} = 58.5, p < .05$, where complex patterns aroused more partial responses (13.55%) than the simple patterns (7.4%).

What about the effect of stimulus duration on these responses? Figure 26 depicted these results as the function of age and duration.

Figure 26. *Percentage of responses in the frame-part analysis as a function of age and duration (A = Frame-correct response, B =Frame-incorrect response, C = Part-correct response, D = Part-incorrect response, E = Frame-absent response, F = Part=absent response, G = Partial response)*



The effect of duration was not significant for three drawing responses, which were : *the frame correct responses* (all $ps > .10$), *the frame incorrect responses* (all $ps > .10$) and *the frame absent responses* (all $ps > .10$), even at 4 years of age as shown in Figure 26A, 26B and 26E respectively. In all the other cases, duration had an impact on the responses produced by the children. As illustrated in Figure 26C, *the part correct responses* were more frequently produced with the long durations (88.1%) than the short durations (67.85%). The effect of duration was significant, $T_{(N=121)} = 69, p < .01$, except at 4 years of age and at 9 years of age (all $ps > .10$).

For the *part incorrect responses* displayed in Figure 26D, a significant effect of duration was found in all ages, $T_{(N=121)} = 198, p < .01$, with the short durations eliciting more these responses (14.9%) than the long durations (5.8%), except at 4 years of age and at 9 years of age (all $ps > .10$).

Figure 26F depicted the results for the *part absent responses*, where an effect of duration was again found, $T_{(N=121)} = 21, p < .01$. Short durations yielded more these responses (10.5%) than the long durations (4.75%). The effect of duration was found at 4 years of age, $T_{(N=20)} = 8, p < .05$, but not at 9 years of age ($p < .10$).

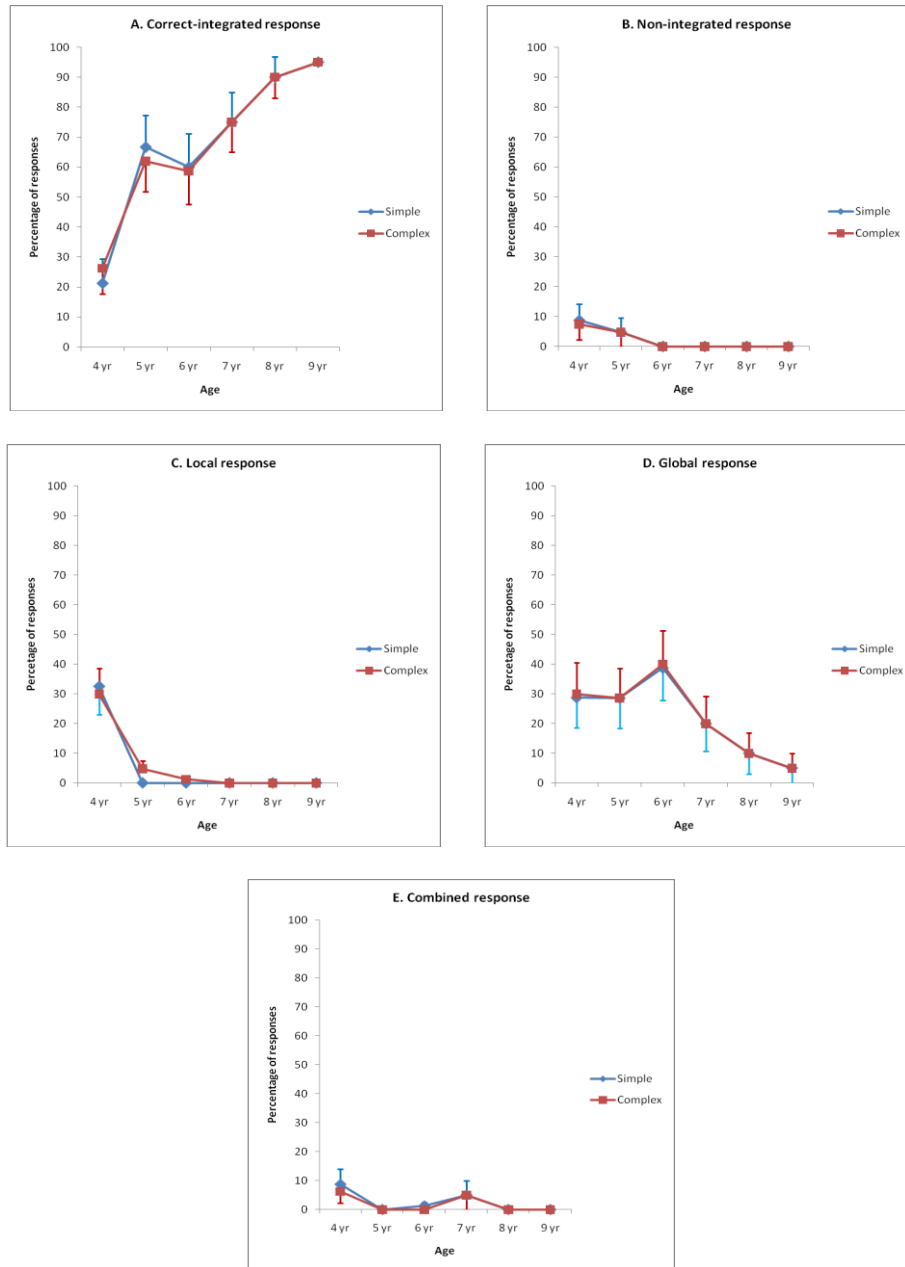
Finally, the *partial responses* (Figure 26G) were more induced by the short durations (7%) than by the long durations (3.7%), $T_{(N=121)} = 48, p < .05$. This occurred particularly at 5-6 years of age, $T_{(N=41)} = 0, Z = 2.6, p < .01$, where the short durations (12.1%) elicited more these responses than the long durations (3.6%).

Note that the effect of sex on the frame-part analysis was never significant, regardless of the type of responses (all $ps < .10$). So this factor was ignored in the rest of the analysis.

2. Results of the categorization analysis of the drawing responses

Let's examine now the results issued from the categorization analysis of the drawing responses in global, local, integrated, non integrated and combined responses. Figure 27 depicts these results as a function of age for the simple and complex stimuli.

Figure 27. *Percentages of the different types of drawing responses in the categorization analysis as a function of age*



The *correct integrated responses*, depicted in Figure 27A, increased progressively and significantly with age, $H_{(5, N=121)} = 36.43, p < .01$. A significant transition was found between 4 and 5 years of age ($U=117.5, n_1=20; n_2=21, p < .05$), and again between 5 and 8 years of age, ($U=134, n_1=20; n_2=21, p < .05$), though they continue to develop until the age of 9 years. An effect of complexity was not found in these responses (all $ps > .10$).

On the contrary, the *non-integrated responses* declined with age as described in Figure 27B, $H_{(5, N=121)} = 20.75, p < .01$, but they were rare, even in the younger ages and they

disappeared by the age of 6 years. No effect of complexity was significant at all ages (all $ps > .10$).

Figure 27C depicted the significantly decreasing *local responses* when age increased, $H_{(5, N=121)} = 39.30, p < .01$. A significant transition appeared between 4 and 5 years of age ($U=123, n_1=20; n_2=21$), $p < .05$, and after the age of 6 years, none of the children produced local responses. No effect of complexity was found across ages (all $ps > .10$).

The *global responses* showed a marginally significant effect of age, $H_{(5, N=121)} = 9.60, p = .08$, as illustrated in Figure 27D. Indeed, if we compared the 4-5-6 year-old children to the 8-9 year-old children, we find that the former produced more global responses (32.4%) than the later (11.7%), ($U=914, n_1=61; n_2=40$), $p < .01$. The effect of complexity was again not significant (all $ps > .10$).

Figure 27E described the *combined responses* which showed a significant effect of age, $H_{(5, N=121)} = 12.612, p < .05$, with these responses decreasing with age although they remained at low frequencies (2.1%), compared to the other responses. No effect of complexity was found (all $ps > .05$).

Figure 28 expressed the frequencies of these categories of drawing responses as a function of duration for the different age groups.

Figure 28. Percentage of responses in drawing for categorization analysis as a function of duration and age

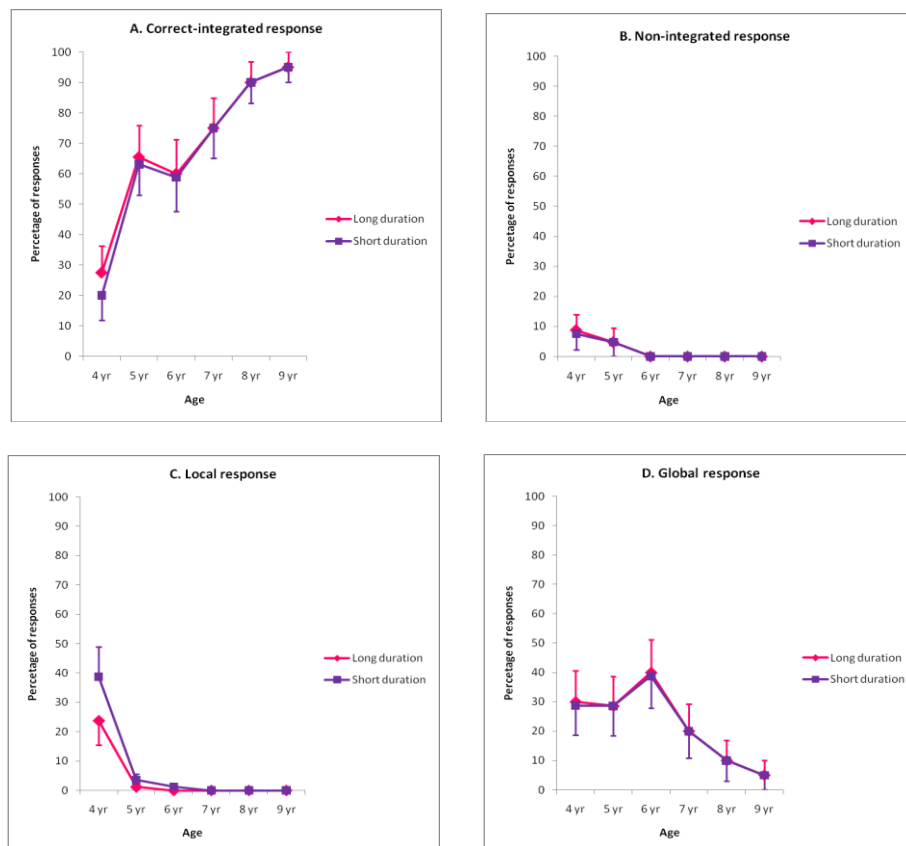
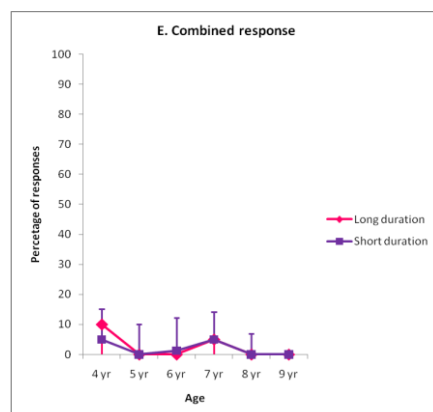


Figure 28. (continued)



The long or short pattern durations showed no significant effect on the production of *integrated responses* as depicted by Figure 28A, as well as the production of *non-integrated responses*, as seen in Figure 28B (all $ps > .10$). Duration had a significant effect only on the production of *local responses*, $T_{(N=121)} = 0$, $Z = 2.66$, $p < .01$, with the local responses elicited more often by the short durations (7.2%) than by the long durations (4.1%). This significant difference was due to the younger children aged 4 years, $T_{(N=21)} = 0$, $Z = 2.2$, $p < .05$. Duration failed to have an impact on the other types of drawing responses (all $ps > .10$).

B. Experiment 4: Similarity judgment task with simple and complex hierarchical patterns

Experiment 3 suggested that children were constructing independently an analysis of the frame and the part before they were able to draw an integrated response, associating correctly the two analyses. The frame-correct analysis increased more rapidly than the part-correct analysis; it emerged between 4 and 5 years of age, and it seemed stable. The complexity of stimuli influenced only the part analysis, with the complex figures less well reproduced than the simple ones at younger ages. It did not influence the other responses. Duration had also a greater impact on part analysis than on frame analysis. With regard to the issue of local-global processing, the results showed that local processing dominated at younger ages and that local and global processing started being integrated at the age of 5.

In Experiment 4, a similarity judgment task was employed to test whether global processing preference would emerge somewhere near 5 years of age, and whether the complexity of the hierarchical patterns would have an impact on this preference. The similarity judgment task was designed so that it was as similar as possible to the drawing task.

The same simple and complex target patterns as used in Experiment 3 were shown to children in Experiment 4 under the same exposure duration conditions. Children had to decide which figure, among four alternatives, was the most similar to the target. We expected to observe a local bias in the choices made by the youngest children, which should be stronger under long rather than short target exposure durations. Experiment 3 did not show any important influence of complexity of the hierarchical patterns on the drawing responses; we expected similar findings in the similarity judgment task. However, the effect of stimulus duration should be greater than to the one seen in Experiment 3.

Method

Participants.

One-hundred children (49 girls), aged between 4 and 10 years, participated in the experiment. They were divided into 5 age groups as described in table 4.

Table 4. *Age distribution of the participants in Experiment 4.*





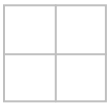

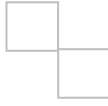
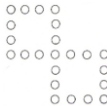



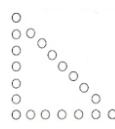



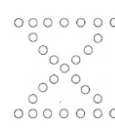
No	Age group	<i>N</i>	<i>M / F</i>	<i>Mean</i>	<i>Range</i>
1	4 yrs	20	13 / 7	4 yr 4 mo	3 yr 10 mo - 4 yr 7 mo
2	5 yrs	20	8 / 12	5 yr 5 mo	4 yr 11 mo - 5 yr 9mo
3	6 yrs	20	9 / 11	6 yr 5 mo	6 yr 0 mo - 6 yr 10 mo
4	8 yrs	20	9 / 11	8 yr 4 mo	7 yr 10 mo – 8 yr 9 mo
5	10 yrs	20	12 / 8	10 yr 4 mo	9 yr 10 mo – 10 yr 9 mo
Total		100	51 / 49		

Each age group corresponded to one school level (4-5-year-olds: nursery and kindergarten levels). The criteria used to select the children were exactly the same as those described in the previous experiments and none of them participated in these previous experiments.

Material.

Like in Experiment 3, the global shape was 4 cm of height and width and each small local shape was 0.3 cm of height and width. The density of local elements was identical to the one used in the previous experiments. As shown by Figure 22, the 4 targets were a square divided into 2 rectangles or into 2 triangles (figures with simple internal parts, hereafter called “simple figures”), or into 4 squares or into 4 triangles (figures with complex internal parts, hereafter called “complex figures”). The stimuli presented as responses’ choices series included a global response (1), a local response (2), a global-partial response (3) and an integrated partial response (4) as seen in Figure 29.

Figure 29. Illustrations of the response choices in the similarity judgment task

SIMPLE STIMULI 1			
 Global - Total	 Local – Total	 Global Partial	 Integrated Partial
COMPLEX STIMULI 1			
 Global - Total	 Local – Total	 Global Partial	 Integrated Partial
SIMPLE STIMULI 2			
 Global - Total	 Local – Total	 Global Partial	 Integrated Partial
COMPLEX STIMULI 2			
 Global - Total	 Local - Total	 Global Partial	 Integrated Partial

Procedure.

During an initial familiarization phase, children got used with the material and the instructions. They were presented with a target stimulus (circle or square) and were asked to select, among four choices (see Figure 29), the stimulus “which was the most similar” to the target, “which looked most alike”. The experimenter told the participants to focus their attention on the screen because, in some cases, the target would appear for a very short time. This phase included 4 trials (circle or square, presented in two durations), and was likely to be repeated once if children selected the wrong choices. The target remained visible for 3 sec or for 300 msec, followed by a blank screen during 800 msec before the 4 choices appeared. The children clicked with the mouse on the stimulus they considered as most alike to the target.

The participants were asked to keep their position constant throughout the experiment. The experimenter checked this point each time before launching the next trial. The familiarization phase was useful to make the children familiar with the pace of the presentation of the targets and with the instructions. Some of the children aged 4 years needed a repetition of the familiarization phase.

The instructions given in the experimental phase were identical to those in the familiarization phase. Four targets were shown in the test phase: 2 were simple stimuli and 2 were complex stimuli. They were displayed either for 3 sec (long duration) or for 300 msec (short duration), and the 4 responses' choices appeared after a blank screen of 800 msec and remained visible on the screen until the children selected one response. The experimenter waited for the participants' ready-signal before launching the next trial. Each target was presented twice in each duration. The targets (simple or complex) as well as the durations (short or long) were randomized across the 16 trials. Four choices were presented to the participants in each of simple and complex target as shown in Figure 29.

For each stimulus, the choices corresponded to a global response (for instance, choice for the square divided by a diagonal), a local response (for instance, choice for the set of small circles), a global partial response (for instance, selection of the triangle as part of square that was divided by a diagonal) and integrated partial response (for instance, choice for the set of circles that resembled to global partial choice). The location of the four responses' choices at the bottom of the screen (left, right or middle) was randomized.

Results

The results are depicted in Figure 30 (A=global responses, B=local responses, C=global-partial responses, D=integrated-partial responses) as a function of age for the simple and complex patterns.

Figure 30. *Percentage of responses as a function of age and patterns in the similarity judgment task*

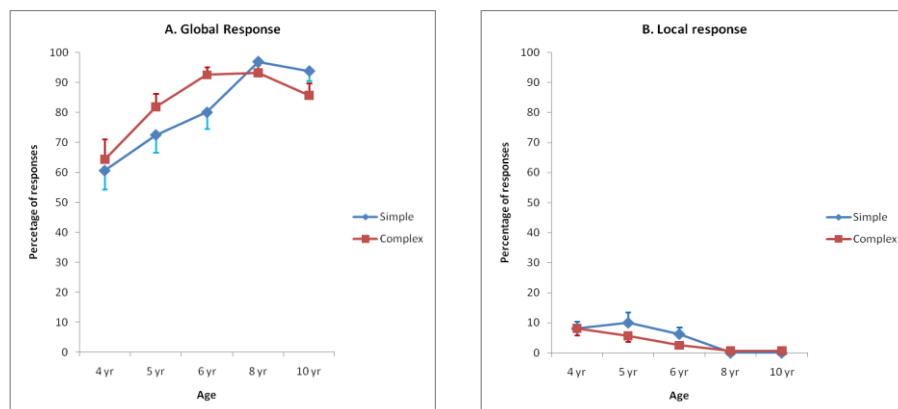


Figure 30. (continued)

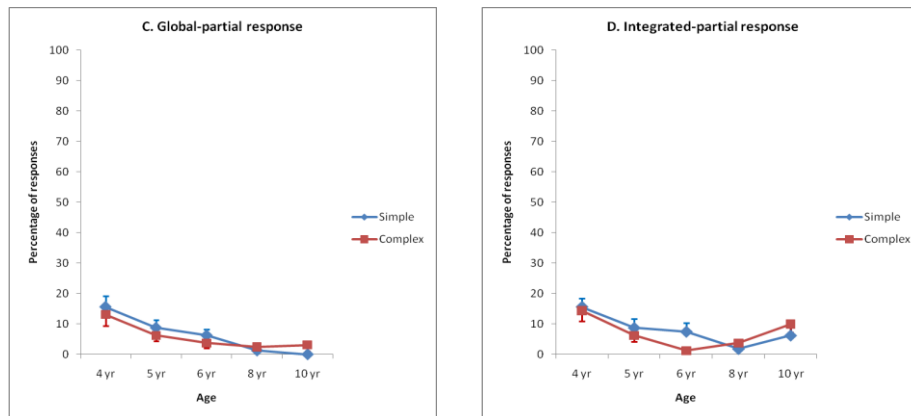


Figure 30A showed that the choice for the *global responses* increased significantly with age, $H_{(4, N=100)} = 23.70$, $p < .01$, though the youngest children pointed to these responses in already a noticeable number of cases (62.5%). A first significant difference was found between 4 and 6 years of age, ($U = 96.5$, $n_1 = n_2 = 20$), $p < .01$. A slight decrease in the occurrence of these responses was observed between 8 (95%) and 10 years of age (89.7%), but no significant difference was found. An effect of the complexity of the stimuli was significantly found between age 4 and 6 years of age, $T_{(N=60)} = 125$, $Z = 3.11$, $p > .01$ with the complex stimuli eliciting more global responses (79.58%) than the simple stimuli (71%). A marginally significant effect of complexity was found at 10 years of age, $T_{(N=20)} = 1.88$, $p = .059$, but contrarily to the former result in older children, the global responses were more aroused by the simple stimuli (37.5%) than by the complex stimuli (25%).

The children selected the *local responses* rarely, on average only in 4% of the cases. Nevertheless, the youngest children did it more often than the oldest ones, $H_{(4, N=100)} = 25.41$, $p < .01$ as illustrated in Figure 30B. The choice for these responses vanished at 8 years of age and the shift in the local responses between 4 and 8 years of age yielded significance, ($U = 76$, $n_1 = n_2 = 20$), $p < .01$. An effect of stimulus complexity was significant at 5 and 6 years of age, $T_{(N=40)} = 9$, $Z = 2.35$, $p > .05$, the simple patterns eliciting more local responses (8.1%) than the complex patterns (4.1%).

The choice for the *global-partial responses* diminished significantly with age as seen in Figure 30C, the youngest children opting for them in 14.4% of the cases while this percentage dropped to 1.6% at 10 years of age, $H_{(4, N=100)} = 21.76$, $p < .01$. Between 4 and 6 years of age, there was a marginally significant drop of these responses, ($U = 132$, $n_1 = n_2 = 20$), $p = .065$. The effect of stimulus complexity yielded no significance for the global-partial responses (all $ps > .10$).

Finally, the *integrated partial responses* (Figure 30D) displayed the more interesting significant evolution with age, $H_{(4, N=100)} = 19.65$, $p < .01$. They decreased between 4-5-6

years of age ($U = 85.5$, $n_1 = n_2 = 20$), $p < .01$, but after 8 years of age, a significant tendency to increase was observed ($U = 126.5$, $n_1 = n_2 = 20$), $p < .05$. At 5 and 6 years of age, a significant effect of stimulus complexity was found, $T_{(N=40)} = 35$, $Z = 2.19$, $p < .05$, with the simple stimuli eliciting more integrated partial responses (8.1%) than the complex stimuli (3.8%).

Let's examine now the impact of pattern duration. The results are shown in Figure 31.

Figure 31. Percentages of responses as a function of age and duration in the similarity judgment task

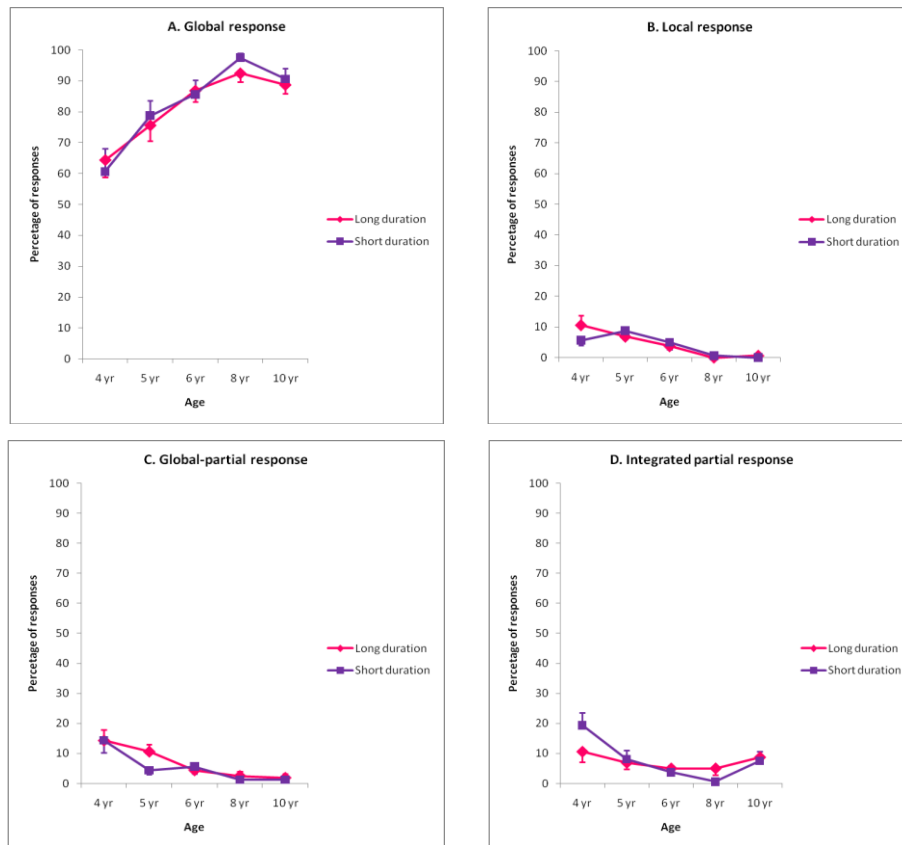


Figure 31A illustrated the percentage of *global responses* as a function of age and duration. A marginally significant difference was found in these responses at 8 years of age, $T_{(N=20)} = 1.5$, $Z = 1.8$, $p = .059$, where the global responses were more elicited by the short durations (97.5%) than by the long durations (92.5%).

Another significant difference as regard to duration was found in the *global-partial responses* at 5 years of age, $T_{(N=20)} = 3.5$, $Z = 2.25$, $p < .05$, as illustrated in Figure 31C. The long durations elicited more global-partial responses (10.6%) than the short durations (4.4%).

No effect of duration were found in the *local responses* as depicted in Figure 31B and also in the *integrated-partial responses* as illustrated in Figure 31D (all $ps > .10$).

Discussion

In this study, the frame and part analysis yielded new findings on how children integrated spatial information in the drawing of hierarchical patterns. Before they reproduced an integrated, a local or a global response, children were constructing the frame and part analysis.

In overall, the results showed that age had an important impact on the development of frame-part analysis. Frame correct responses increased rapidly between 4 and 5 year of age, and then it seemed stable. Part correct responses also increased with age but less rapidly than the frame correct responses. A reverse result was shown for all the incorrect frame-part and absent frame-part responses, as these responses tended to decrease as age increased. The significant shift in the frequencies of these responses was also found between 4 and 5 years of age.

Complexity of the stimuli significantly influenced the part-correct responses, the part-incorrect responses and the partial responses and did not influence any frame responses. A similar result was observed for the effect of duration that was found only in the production of part-responses. Long durations triggered more part-correct responses, while the part-incorrect, the part-absent and the partial responses were more produced under of short durations, which could mean that short durations caused more defaults in the drawing of the parts than of the frame.

Age had also an important effect in the categorization analysis. The *correct integrated responses* increased progressively and significantly with age, while the other responses (non-integrated, global and local responses) significantly tended to decrease as age increased. As compared to the local responses, the global responses dominated, and they decreased after 6 years of age. This shows that children at younger ages can attend to both the local and global level but these responses tended to decrease as children get older and began to integrate the local and global level into an integrated response.

Duration had an effect on the local responses, with the short durations eliciting more local responses than the long durations. It occurred at younger ages (4 years of age) and this might support other findings which proposed that local preference existed in children at younger ages.

This study suggests that the integration between local and global levels of organization in drawing seems to emerge at 5 years of age. Before 5 years of age, children are able to focus on the global level or local level, but they cannot coordinate and integrate the two levels (76.25% of drawing performance at the age of 4 was either local, or global, or non-integrated). The dominance of global processing accounted for the more rapid development of the drawing of the frame, as compared to the drawing of the parts, evidenced

by 42.5% of the children who showed frame-correct responses at the age of 4 (100% at the age of 7). Part-correct responses were shown by 36.25% of the children at the age of 4 and gradually increased to 90.6% at the age of 7 without reaching 100% at the age of 9 (it presumably continued to develop after the age of 9).

In this study, the development of spatial analysis in drawing was globally not influenced by the complexity of the pattern and by the duration of the display. The effect of complexity and duration only significantly influenced the reproduction of parts.

The findings obtained in the similarity judgment task confirmed that that age had a significant effect on global responses, local responses, global-partial responses and integrated-partial responses. The predominant responses were clearly the global responses: at 4 years of age, children selected these responses in already more than 60% of the cases. A peak was reached at 8 years, followed by a slight but not significant decline at 10 years. Furthermore, these global responses were more enhanced by the complex figures in children between 4 to 6 years of age, but at older ages (8 years of age and henceforth), the simple figures elicited more the global responses than the complex figures. The choice for the local responses was very rare in the present experiment, even at the youngest ages (less than 10% of the cases). They were no longer observed at 8 and 10 years of age. The global-partial responses showed a similar evolution, disappearing at older ages, and on the contrary, the integrated-partial responses showed a tendency to increase in older children.

The effect of complexity was evidenced in the choice for local responses and for integrated-partial responses. The simple patterns elicited more these responses than the complex ones. No effect of complexity was found in the global-partial responses.

Duration on the other hand had a significant impact only on the global responses and global-partial responses. The short durations elicited more global responses although it only occurred at 8 years of age. On the contrary, the long durations elicited more global-partial responses in children at 5 years of age.

From these two explanatory experiments, we can conclude that the children's spatial analysis of simple and complex hierarchical patterns developed from local to global at younger ages (between 4 to 5 years of age), these local and global responses beginning to integrate at between 6 to 7 years of age. These conclusions were supported by the evidence that younger children produced more local responses than older children in the drawing task and in the similarity-judgment task. The frame-part analysis ensured this idea since children at younger ages gave more incorrect responses in drawing the global level or the frame.

The global responses were dominant after 5 years of age in the similarity-judgment task, illustrating the global advantage effect. In the drawing task, they showed a tendency to decrease as age increased, because this task required an integration of the two processes to be successfully achieved. Indeed, when the global responses decreased, responses based on

integration began to consistently increased, as evidenced by the production of more frame and part-correct responses in the drawing task and of correct-integrated responses in the similarity-judgment task.

Complexity of the patterns enhanced the production of incorrect and partial responses, both in the drawing task and in the similarity-judgment task in children at younger ages. On the contrary, after 6 years of age, complexity of the patterns elicited more part correct responses. This finding might support the idea that children at older ages attended to more detailed information in order to integrate the two levels of analysis (global and local) in the responses. This conclusion is coherent with the evidence that long durations elicited more part-correct responses in children. The significant effect of durations was also consistently found in the production of incorrect part responses and partial responses in the drawing task where short durations elicited more incorrect and partial responses.

CHAPTER 4. Spatial Analysis of Hierarchical Meaningful Patterns in Children with Mental Retardation: Naming task and Drawing Task

Introduction

The aim of this research was to study spatial analysis abilities in children with Mental Retardation (MR) in a naming task and a drawing task, using hierarchical meaningful patterns. We expected that meaning would interact with the global precedence principle advocated by Navon (1977), enhancing therefore a local analysis when meaning was identified at the local level, not at the global level. Furthermore, we aimed at confirming a major global bias in children with mental retardation, though some contradictory results exist in the literature.

There are several studies in the literature that had investigated the perception of hierarchical patterns in people with mental retardation. Some authors working with children with William Syndrome (WS) reported that these children were more accurate in drawing the local elements than they were in drawing the global shape (Bellugi et al., 2000; Rondan et al., 2007; Nakamura, Mizuno, Douyuu, Matsumoto, Kumagai, Watanabe & Kakigi, 2009). Other studies in children with Down Syndrome (DS) revealed that these individuals performed better in drawing the global shape than the local elements (Birhle, et al., 1989; Bellugi et al., 1990; Bellugi, Lichtenberger, Mills, Garaburda & Korenberg, 1999). Farran et al. (2003), reported that individuals with WS showed local bias only in drawing and not in a perceptual task requiring stimulus identification. They suggested that the local bias was not due to perceptual processing but from difficulties in integrating the parts into a whole when producing the drawing. This work was supported by Porter and Coltheart (2006), who reported local advantage in the drawings of individuals with WS, while global advantage was found in individuals with DS. These different findings showed that further investigation of spatial analysis in hierarchical stimuli in children with mental retardation was needed.

A drawing task was used in this research since studies investigating the global-local preference in a drawing task were scarce and showed contradictory results (Lange-Küttner, 2000; Dukette & Stiles, 2001; Vinter et al., 2010). According to Lange-Küttner (2000), most children in younger ages (5 year-olds) tended to draw global shapes when they were asked to copy hierarchical patterns, while older children (11 year-olds) produced correct drawings both at the local and global level. A study by Dukette and Stiles (2001) with children aged 4 to 8 years and adults showed that the youngest children had more difficulties in reproducing the global shape than the local elements if they drew under constrained task conditions (like drawing from memory rather in copying condition), although they were able to attend to both levels of analysis.

Studies that have introduced objects in the building of hierarchical patterns were based on the assumption that objects should arouse automatic identification. Automatic identification at the global or local level should influence global or local precedence respectively. Based on this idea, the present study will use objects as meaningful stimuli and non-objects as non-meaningful stimuli. Meaningful hierarchical patterns included objects that were well-known by the children (eg. star, umbrella, cups, etc) and non-meaningful hierarchical patterns included abstract objects that did not resemble to any object that might be known by children.

Studies that have been done with meaningful hierarchical patterns were pioneered by Poirel et al. (2006, 2008). Using a same/different task in adults (deciding whether two patterns were the same or different), they revealed that (a) target differences were detected more rapidly when the level contained at least one meaningful object; (b) when the irrelevant level contained a pair of non-objects, global preference effects emerged; but when it contained a meaningful object, then local-level targets were detected more rapidly than global-level targets, (c) irrelevant objects did not influence reaction times when there were objects at both levels in the target level. The presence of an object (familiar pattern) triggered an automatic identification process that facilitated performance when it occurred at the target level, and interfered with performance when it occurred at the irrelevant level. These results thus suggested that when a familiar or identifiable object was present, an extra process was triggered and interfered with the performance in the comparison task. Therefore, the authors proposed that there are at least two processes working in parallel in the task, namely an object identification process and a structural analysis. Object identification was involved when a pattern depicted a familiar object, and structural analysis was involved in the comparison between the two patterns displayed during the comparison task. These results not only challenged the global precedence effect in a way that the global level was not always processed before the local one; they also showed that local interference existed.

The authors continued this work to reveal whether this automatic object identification followed the same characteristics in children (Poirel et al., 2008). Children 4 to 9 years of age participated in the study using a similarity judgment task. As in adults, the results showed that children detected the pictures as the same or different more accurately if the stimuli were objects. This finding supported the idea that the identification process was facilitated by the familiar patterns.

This question of the influence of meaning in the processing of hierarchical patterns was interesting to introduce in children with mental retardation. Indeed, we can suspect that the effect of meaning will be important in children with mental retardation, because of their less efficient executive functions. We also expect that the use of objects at the local level will enhance local processing in these children.

Thus, the objective of utilizing a naming task and a drawing task of hierarchical patterns with meaningful and non-meaningful objects was to investigate whether the meaning of objects at the local level would challenge the global advantage's tendency in children with mental retardation.

Method

Participants.

Ninety-four children (36 girls) with mental retardation aged 6 to 14 years participated in the experiment. They were divided into 3 groups of age (see table 5). There was no clear information about the etiology of mental retardation for each child, but most of them showed mental retardation due to organic causes. None of them had a William Syndrome, however. Three groups of IQ were used in this experiment (see table 6). All participants attended specific educational schools in Jakarta (Indonesia) and they were all monolingual Indonesian-native speakers. Children came from families with low to middle-high socioeconomic status. They were observed individually by an experimenter in a quiet room in their school. Informed consent was obtained from parents of each child participating in the study.

Table 5. *Age distribution of participants in the naming task*

No	Age group	<i>N</i>	<i>M / F</i>	<i>Mean</i>	<i>SD</i>	<i>Range</i>
1	6-10 yrs	37	21 / 16	9 yr 4 mo	1 yr 3 mo	6 yr 5 mo-10 yr 11 mo
2	11-12 yrs	26	14 / 12	12 yr 0 mo	0 yr 6 mo	11 yr 0 mo-12 yr 11mo
3	13-14 yrs	31	23 / 8	13 yr 10 mo	0 yr 7 mo	13 yr 0 mo-14 yr 10 mo
Total		94	58 / 36			

Table 6. *IQ distribution of participants in the naming task*

No	IQ group	<i>N</i>	<i>M / F</i>	<i>Mean</i>	<i>SD</i>
1	50-60	37	24 / 13	54.13	4.00
2	61-65	31	20 / 11	62.96	1.30
3	66-70	26	14 / 12	68.34	1.85
Total		94	58 / 36		

In the drawing task, some children ($N = 8$) did not participate because they felt that they were not able to complete the task and they refused to be persuaded. Eighty-six children aged between 6 and 14 years (33 girls) completed the drawing task. They were also divided into three age groups (see table 7) and into three groups of IQ's as described in table 8.

Table 7. *Age distribution of participants of the drawing task*

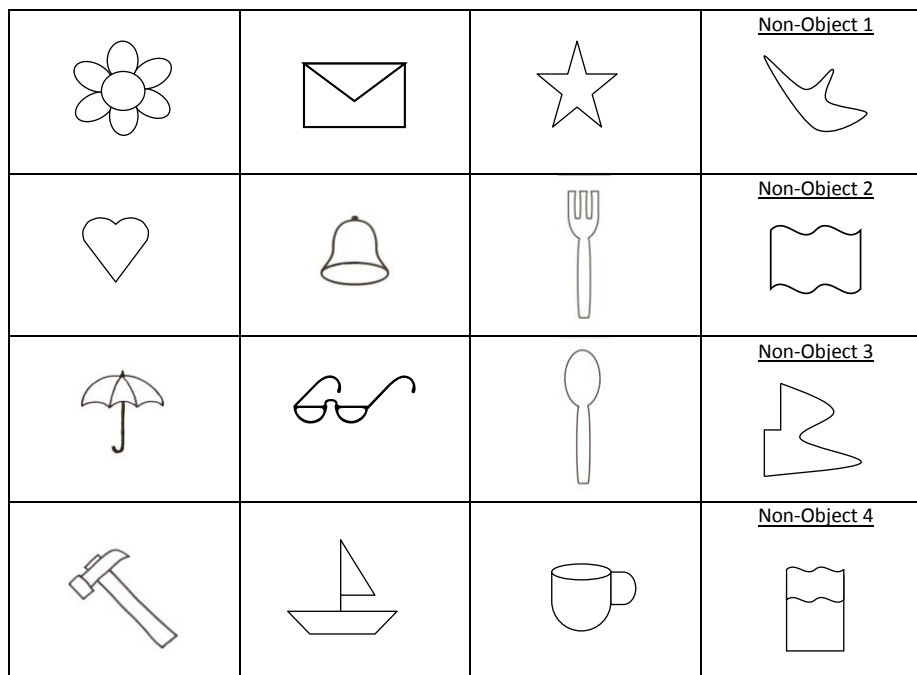
No	Age group	N	M / F	Mean	SD	Range
1	6-10 yrs	35	20 / 15	9 yr 3 mo	1 yr 4 mo	6 yr 5 mo-10 yr 11 mo
2	11-12 yrs	23	11 / 12	11 yr 10 mo	0 yr 6 mo	11 yr 0 mo-12 yr 11mo
3	13-14 yrs	28	22 / 6	14 yr 0 mo	0 yr 7 mo	13 yr 0 mo-14 yr 10 mo
Total		86	53 / 33			

Table 8. *IQ distribution of participants of the drawing task*

No	IQ group	N	M / F	Mean	SD
1	50-60	34	22 / 12	54.38	4.07
2	61-65	29	19 / 10	62.96	1.32
3	66-70	23	12 / 11	68.56	1.82
Total		86	53 / 33		

Material.

The hierarchical meaningful stimuli were built running a preliminary experiment. Thirty-five children with MR aged 7 to 14 years were asked to name or identify 16 pictures (Figure 32). Twelve object pictures were chosen from educational books for pre-school children and also designed by us, and 4 non-object pictures were designed by us using the object design from Microsoft-Word 2007. When children named the object correctly or understood what the object was, explaining the use of the object, they got a score of 1 (0 for incorrect response). They got a score of 0 if they could not explain or did not understand what a non-object was and 1 if they confused the non-object with some object that they knew.

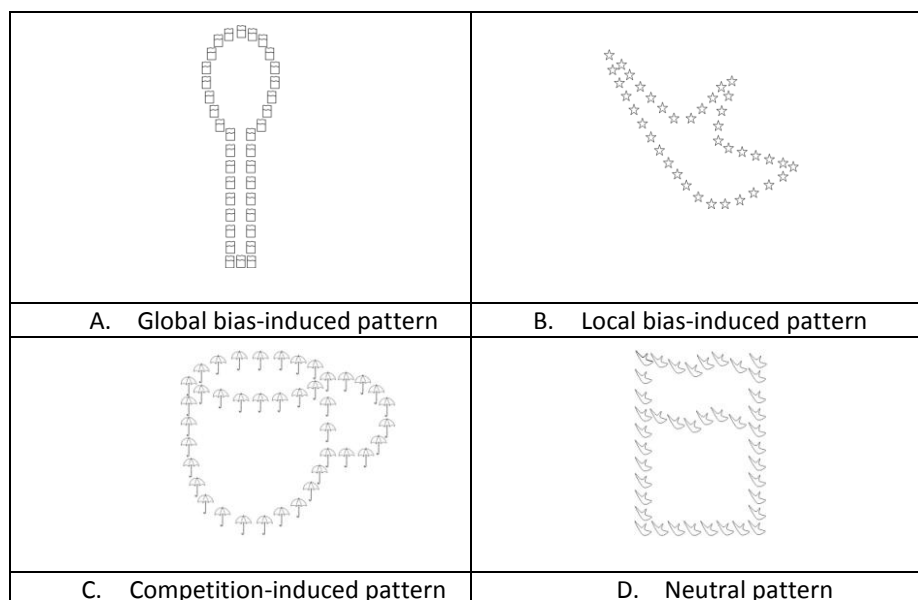
Figure 32. *Pictures of objects and non-objects used in the preliminary experiment*

Object pictures with the highest percentages of recognition were chosen as meaningful stimuli, while the non-object pictures with the lowest percentages were chosen as non-meaningful stimuli. Seven objects (boat, eyeglass, umbrella, cup, fork, star, and spoon) had the highest percentages (88.57% to 97.14%) and 2 non objects (Non-Object 1 and Non-Object 2) had the lowest percentages of recognition (11.43% and 5.72%).

Eight hierarchical stimuli were assessed to determine the validity of the task. The global shape consisted of 40 local elements (Poirel, 2006). The designs were: 2 global shapes of meaningful object with non-meaningful objects at the local level (global bias-induced pattern); 2 global shapes of non-meaningful objects with meaningful objects at the local level (local bias-induced pattern); 2 global shapes of meaningful object with meaningful objects at the local level (competition-induced pattern) and 2 global shapes of non-meaningful objects with non-meaningful objects at the local level (neutral pattern).

Six judges were involved in the validity phase. They gave ranks of suitability for each stimulus whether it had the characteristic of “wholeness”. The ranking score extended from 1 = not suitable at all to 5 = very suitable. The results showed that four hierarchical stimuli had individually higher mean of ranking scores (range from 3.66 to 4.16) than the total mean of ranking score (3.104). Those four hierarchical stimuli were utilized in the main experiment (Figure 33).

Figure 33. *Stimuli used in the main experiment*



Procedure.

The four stimuli were presented to the children using a Power Point Presentation in 15 inch screen laptop. The local elements fit within rectangles of 1.26° height and 1.26° width, in terms of visual field, so the global shape, the hierarchical patterns were approximately 11.4° in width and 8.5° in height.

In a short familiarization phase, the children were introduced to the instructions and experimental conditions. They were instructed to identify the pattern they were being to see on the screen and then “to copy as accurately as possible the model which appeared on the screen”. They were told to concentrate their attention to the screen. One hierarchical pattern was used in the familiarization phase (a triangle for the global shape and circles as local elements) to train the participants with the instructions. The experimenter gave them one sheet of paper (A4 format) and a black pencil, and asked them to sit comfortably at a distance of about 60 cm from the screen. The participant’s body midline corresponded to the middle of the screen. There was no time constraint although the experimenter noted how much time the children needed to finish every pattern. When the pattern on the screen was identified, the children were instructed to draw the pattern. A further probing was applied by the experimenter before the drawing task, if the children did not answer very clearly, especially for the non-object patterns. As drawing was finished, the experimenter took away the response paper and gave a new one to the participants. The experimenter waited for the participant’s readiness signal before displaying the next hierarchical stimulus.

Data Coding.

We proceeded to a close inspection of the entire set of data in the naming task and in the drawing task. This enabled us to sort the responses into different categories as follows for the naming task first :

- ***Integrated response*** : Children named the local elements as well as the whole shape. Since the patterns contained non-objects, a probing was needed, for the responses not being confused with non-integrated responses. When children could not described clearly a non-object but they mentioned the shape of this non-object, then the answer will be considered as integrated response. The same condition applied if children named the non-object pattern using the name of an object that resembled to the non-object pattern (eg. a boat made of little stars for the local bias-induced pattern or a flag made of small shoes for the neutral pattern).
- ***Non-integrated response*** : Children responded with objects which did not correspond to the given pattern. For the non-objects, children’s answer was considered as non-integrated if





















they didn't answer at all or when they answered with objects which had very different characteristics from the given pattern (eg. a ball for the local bias-induced pattern).

- **Global response** : Global bias-induced pattern and competition-induced pattern which have clear definition for the global response, did not need any further probing, but for the global patterns which were non-objects (as in the case of local bias-induced pattern and neutral pattern), a probing was needed. The experimenter asked children about the size of the pattern and the number of patterns that they mentioned to determine whether it was a global response or a local response (e.g. Consider children said "star" for the local bias-induced pattern, then the experimenter asked, "is it a big star or a small star?" or "how many stars do you see in the picture?").

- **Local Response** : As for the global responses, the patterns composed of clear small object patterns were easy to categorize (as in local bias-induced pattern and competition-induced pattern), but the non-object local figures needed further clarification. The experimenter again asked about the size and the number of local elements that the children perceived in the pattern to determine whether it was a global or a local response.

The drawings were also classified into 4 categories as illustrated in Figure 34. The categories were:

Figure 34. *Examples of drawings for data coding*

Integrated (accurate)				
Integrated (inaccurate)				
Undifferentiated/ Syncretic				
Global				
Local				

- ***Integrated response***: the global shape as well as the local elements was reproduced. Accurate (good shape) and inaccurate (deformed) responses were not distinguished since we were not interested in the accuracy of the reproduction of the local and global shapes, but in their integration.
- ***Undifferentiated/Syncretic response***: neither the global shape nor the local elements were reproduced and the responses were only scribbles of syncretic lines and curves.
- ***Global response***: global shapes were reproduced, but the local elements were absent.
- ***Local response*** : a series of local elements were reproduced, but they were either isolated or linked one to the other, yet forming only a part of the target, so that the global shape was absent.

Two judges coded the drawings independently. The percentages of agreement between the two judges were 86% for the integrated responses, 97.2% for the undifferentiated/syncretic responses, 97.3% for global responses and 84.2% for the local responses. Since there should only be one score for each hierarchical stimulus in the analysis, the judges had to settle any disagreement in their scoring.

Results

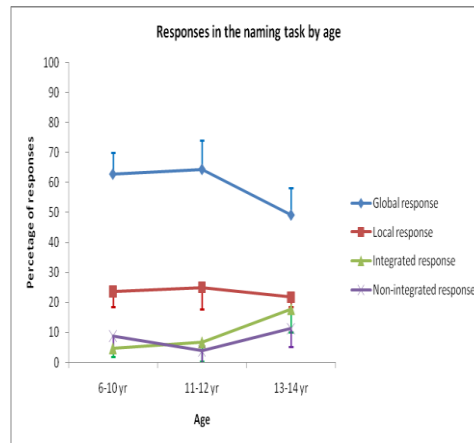
C. Results from the naming task

The data were analyzed by using non-parametric tests because the assumption for the homoscedasticity was not met in most of the cases. The Kruskal-Wallis test (H value) was applied to test overall age differences, the Mann-Whitney test (U value) to test age and IQ differences between two groups, the Friedman Anova test (F value) was used to test the effects induced for the different patterns and the Wilcoxon signed-rank test (T value) was employed to test differences between two patterns. Two analysis of the data were completed : one taking age as the main independent factor, and one taking IQ as the main factor. They are presented separately.

1. Analysis as a function of age

Figure 35 illustrated the overall responses of children across meaningful and non-meaningful hierarchical patterns in the naming task as a function of age.

Figure 35. *Percentages of responses (global, local, integrated and non-integrated) in the naming task as a function of age*



No significant effect of age was found in these responses (all $ps > .10$), despite the tendency of global responses to decrease between 11-12 and 13-14 years of age and the tendency of integrated response to increase during these ages. The frequency of these responses differed significantly, $F_{(N = 94, df = 3)} = 79.68$, $p < .01$. The global responses were dominantly performed by the children with mental retardation (58.8%), followed by the local responses (23.4%). The integrated responses and non-integrated responses remained at a low level (9.6% for the integrated responses and 8.2% for the non-integrated responses),

A more detailed view of the data can be obtained by examining how the responses evolved as a function of the type of patterns shown to children. These results are illustrated in Figure 36.

Figure 36. *Percentages of responses as a function of patterns and age in the naming task*

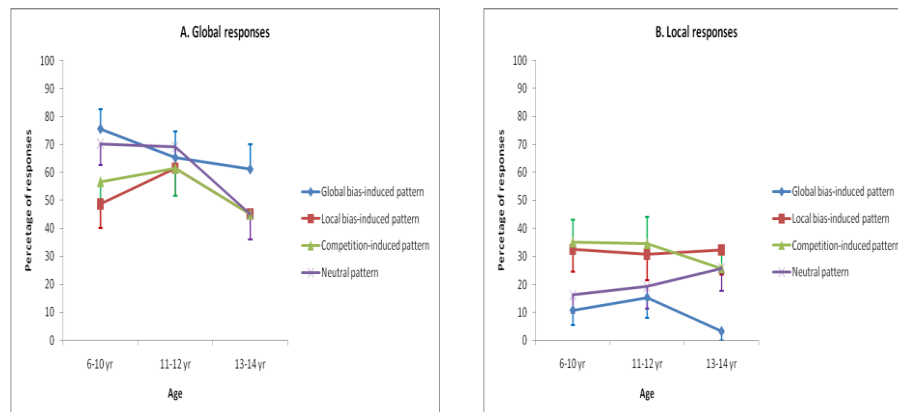


Figure 36. (continued)

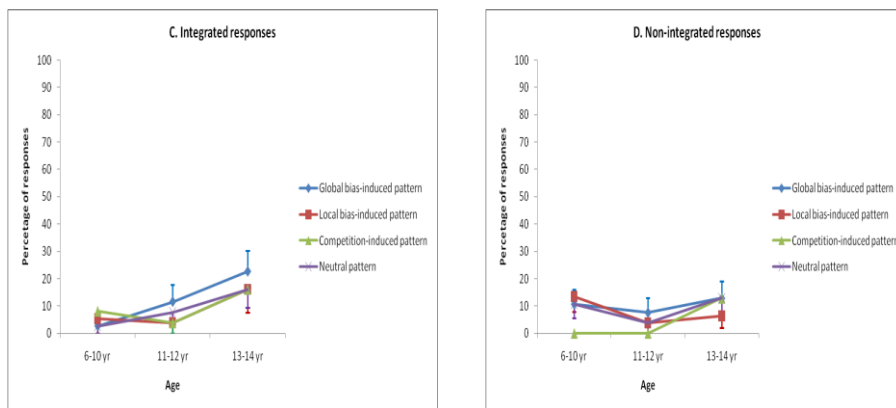


Figure 36A depicted the frequencies of the *global responses* across the patterns. No significant age effects were found for the global bias-induced pattern, the local bias-induced pattern, and the competition-induced pattern (all $p_s > .10$). A marginally significant effect of age only emerged for the neutral pattern, $H_{(2, N=94)} = 5.30$, $p = .07$, with the global responses decreasing as age increased.

The differences of effects induced by the different patterns were also found significant, $F_{(N=94, df=3)} = 17.04$, $p < .01$. The global responses were more induced by the global-bias pattern (68.1%) and neutral pattern (61.7%), while less global responses were elicited by the competition-induced pattern (54.25%) and the local bias-induced pattern (51.1%) although these frequencies of global responses remained high, compared to the other responses.

A significant difference was also found between the global responses elicited by the global bias-induced pattern and the local bias-induced pattern, $T_{(N=94)} = 50$, $Z = 2.84$, $p < .01$. The global bias-induced pattern elicited more global responses (67.45%) than the local bias-induced pattern (51.8%). This difference was mainly found at age 6-10 years, $T_{(N=37)} = 6.5$, $Z = 2.54$, $p < .05$. A similar significant difference was found in the production of global responses elicited by the global bias-induced pattern compared to the competition-induced pattern, $T_{(N=94)} = 44$, $Z = 2.84$, $p < .05$. The global bias-induced pattern elicited more global responses (67.45%) than the competition-induced pattern (54.5%). This difference was significant in children aged 6-10 years, $T_{(N=37)} = 0$, $Z = 2.36$, $p < .05$.

The *local responses* as illustrated in Figure 36B, showed no significant age effects across the different patterns (all $p_s > .10$), but these frequencies differed significantly as a function of the type of patterns, $F_{(N=37, df=3)} = 33.38$, $p < .01$. The local responses were not only more induced by the local bias-induced pattern, but also by the competition-induced figure (both indicated that children gave local responses in 31.9% of the cases).

The local responses were more produced in face of the local bias-induced pattern (31.9%) compared to the global bias-induced pattern (9.5%), $T_{(N = 37)} = 0$, $Z = 4.01$, $p < .01$. A similar result was found comparing the local responses induced by the competition-induced pattern and the global-bias pattern, $T_{(N = 37)} = 12$, $Z = 3.84$, $p < .01$. The competition-induced figure elicited more local responses (31.9%) than the global bias-induced figure (9.5%).

The local-bias patterns induced more local responses (31.9%) than the neutral pattern (20.2%), $T_{(N = 37)} = 40$, $Z = 2.21$, $p < .01$. Thus, a local preference emerged when a meaningful object was used at local level, although the global responses dominated most of the responses in children with mental retardation.

The *integrated responses* illustrated in Figure 36C showed a significant age effect when they were produced by the global bias-induced pattern, $H_{(2, N = 94)} = 6.38$, $p < .05$. The integrated responses were more frequent in older children (22.6%) than in the younger ones (1.2%).

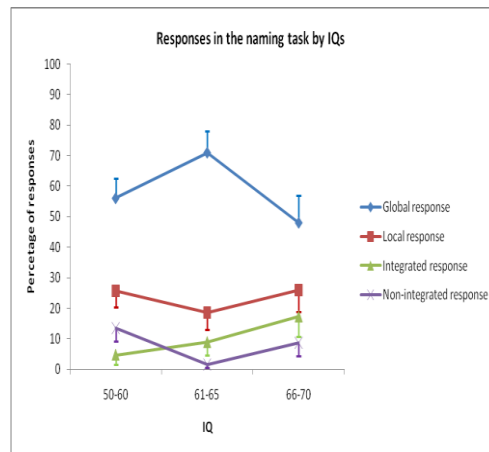
The *non-integrated responses*, shown in Figure 36D, were rare at all ages, and they did not show any interesting effects as a function of age or patterns (all $ps > .10$).

2. Analysis as a function of IQ

The same analysis was applied grouping the data as a function of IQ, as illustrated in Figure 37. Three groups of IQs were reported in the analysis. The first group was composed of children with IQs (Wechsler scale) = 50-60 (henceforth called lower IQ-group), the second group were made of children with IQs = 61-65 (henceforth called middle IQ-group) and the third group included children with IQs = 66-70 (henceforth called higher IQ-group).

Children's responses grouped by IQs showed a dominance of global responses. A significant effect of IQ was marginally found in the integrated responses, $H_{(2, N = 94)} = 5.27$, $p = .071$ and non-integrated responses, $H_{(2, N = 94)} = 5.38$, $p = .067$. Children in the lower IQ-group produced less integrated responses (4.3%) than children in the higher IQ-group (17.3%).

Figure 37. Percentages of responses in the naming task as a function of IQ



The non-integrated responses showed a slightly reverse result, with children in the lower IQ-group producing more non-integrated responses (13.5%) than children in the higher IQ-group (8.65%).

A further examination of the effect of IQ on children's performance as a function of the type of patterns shown to children was also worth to be explored. These results are illustrated in Figure 38. Figure 38A reported the production of *global responses* in the naming task in children with mental retardation as a function of IQ. The results showed that the global responses dominated. A marginally significant effect of IQ was found in the global responses when they were elicited by the local bias-induced patterns, $H_{(2, N = 94)} = 5.28$, $p = .071$ and by the competition-induced patterns, $H_{(2, N = 94)} = 5.39$, $p = .067$. In both cases, the global responses were more frequent in the middle IQ-group than in the lower IQ-group, and less frequent in the higher IQ-group than in the middle IQ-group.

Figure 38. Percentages of responses in the naming task as a function of IQ

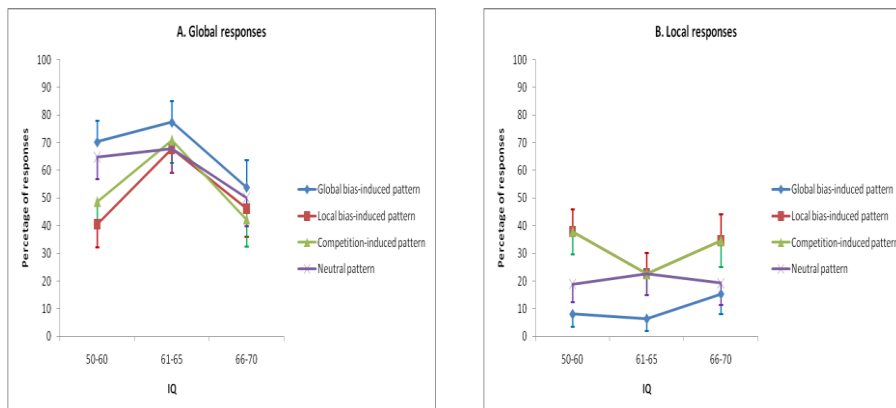
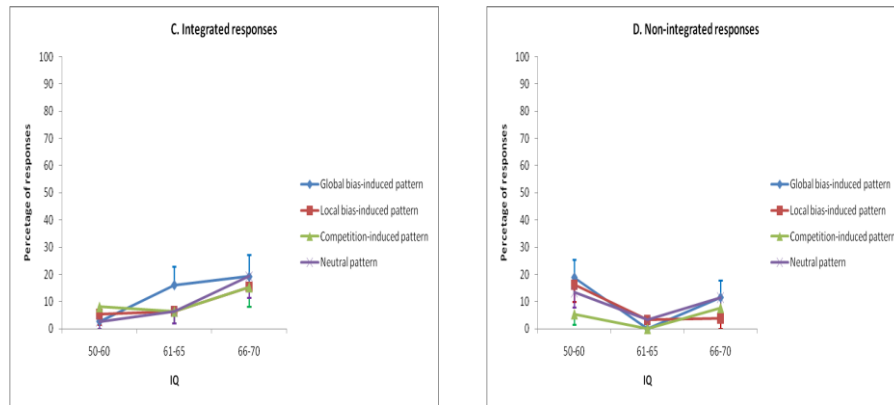


Figure 38. (continued)



Significant differences in the global responses as a function of patterns were found, $F_{(N=94, df=3)} = 17.03$, $p < .01$, especially in the lower IQ-group, $F_{(N=37, df=3)} = 16.01$, $p < .01$, where global bias-induced patterns elicited more global responses (70.3%), followed respectively by the neutral pattern (64.9%), competition-induced pattern (48.6%) and local bias-induced pattern (40.5%). No significant differences in the global responses as a function of patterns were found in the middle IQ-group and higher IQ-group (all $ps > .10$).

The global bias-induced pattern elicited more global responses (68.1%) than the local bias-induced pattern (51.1%), $T_{(N=94)} = 50$, $Z = 2.85$, $p < .01$. This difference existed mainly in the lower IQ-group, $T_{(N=37)} = 5.5$, $Z = 2.24$, $p < .05$. The global bias-induced pattern elicited more global responses (68.1%) than the competition-induced pattern (54.25%), $T_{(N=94)} = 44$, $Z = 2.48$, $p < .01$. Again, this difference was evidenced in the lower IQ-group, $T_{(N=37)} = 5.5$, $Z = 2.24$, $p < .05$. No significant differences in the global responses induced by the global-bias pattern or by the neutral pattern were observed.

Figure 38B showed no significant effect of IQ in the production of local responses, but there was a significant effect of the patterns, $F_{(N=94, df=3)} = 33.38$, $p < .01$, in each IQ-group (all $ps < .01$). The local-bias induced pattern and competition-induced pattern elicited more local responses (31.9%) than the global bias-induced pattern (9.6%), $T_{(N=94)} = 0$, $Z = 4.01$, $p < .01$. A similar difference occurred between the local bias-induced pattern and the neutral pattern, $T_{(N=94)} = 40$, $Z = 2.21$, $p < .05$, mainly in the lower IQ-group, $T_{(N=37)} = 5$, $Z = 2.07$, $p < .05$, where again the local-bias induced pattern and competition-induced pattern elicited more local responses (31.9%) than the neutral pattern (20.2%).

Figure 38C depicted the results for the *integrated responses*. Although they remained at low frequencies (only about 9.6%), a marginally significant effect of IQ was found in the integrated responses elicited by the global bias-induced pattern, $H_{(2, N=94)} = 4.86$, $p = .087$. The integrated responses were more produced in the higher IQ-group (19.2%) than in the lower IQ-group (2.7%). A marginally significant effect of IQ was also found in the integrated responses aroused by the neutral pattern, $H_{(2, N=94)} = 5.55$, $p = .062$. They were more

produced by the children in the higher IQ-group (19.2%) than in the lower IQ-group (2.7%). No significant effect of patterns was found in the production of integrated responses (all $ps > .10$).

The *non-integrated responses* illustrated in Figure 38D showed a significant effect of IQ for the global bias-induced pattern, $H_{(2, N = 94)} = 6.31$, $p < .05$. The frequency of the responses was lower in the higher IQ-group (11.5%) than in the lower IQ-group (18.9%).

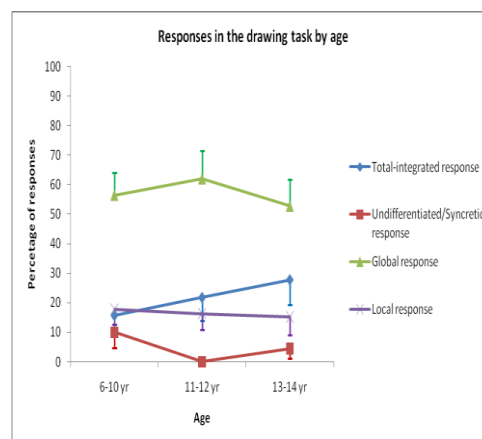
In this study, sex was worth to be investigated since it was considered as a factor that may contribute in children's perceptual analysis. However, no significant sex differences emerged in the present experiment (all $ps > .01$), so no further analysis was reported in this study.

D. Results from the Drawing Task

1. Analysis as a function of age

Figure 39 illustrated the responses of children across meaningful and non-meaningful hierarchical patterns in the drawing task as a function of age.

Figure 39. Percentages of responses (global, local, integrated and non-integrated) in the drawing task as a function of age



No effects of age were found for the different responses (all $ps > .10$) but the interesting finding was the fact that *the global responses* were still dominant (56.7%) in the drawing task as in the naming task, compared to the other responses.

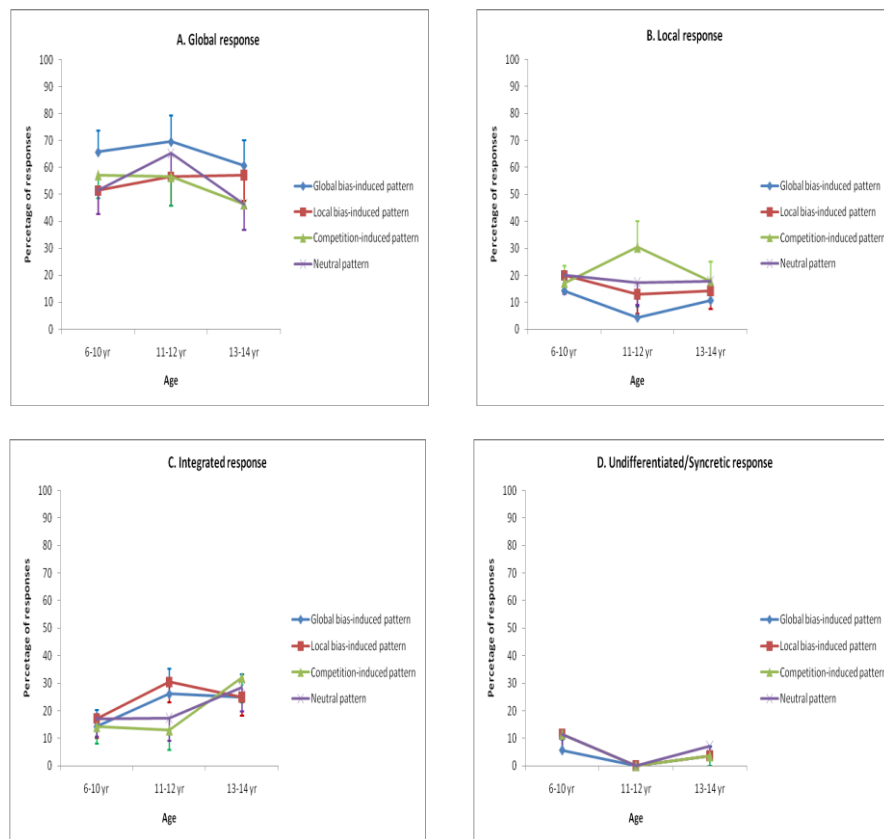
The *total-integrated responses* tended to increase as age increased (15.7% in children at younger ages and 27.7% in older ages). On the contrary, the undifferentiated/syncretic response showed a tendency to decrease as age increased (10% in children at younger ages

and 4.5% at older ages), but no significant effect of age was found in both responses (all $ps < .01$).

Sex had no significant effects on the drawing responses (all $ps > .10$), so it will not be reported further in this study.

A more detailed examination of the data was needed in order to understand how these responses developed as a function of the type of patterns. Figure 40 illustrated these results.

Figure 40. *Percentage of responses as a function of patterns and age in the drawing task*



The *global responses* depicted in Figure 40A showed no significant effect of age (all $ps > .10$), but a significant effect of pattern was found, $F_{(N = 86, df = 3)} = 15.43$, $p < .01$. The global bias-induced pattern elicited more global responses (65.1%) than the local bias-induced pattern (54.65%), $T_{(N = 86)} = 6$, $Z = 2.4$, $p < .05$. It also elicited more global responses (65.1%) than the competition-induced pattern (53.4%), $T_{(N = 86)} = 6.5$, $Z = 2.54$, $p < .05$ and the neutral pattern (53.5%), $T_{(N = 86)} = 0$, $Z = 2.80$, $p < .01$.

Figure 40B illustrated the *local responses*. The competition-induced pattern elicited more local responses (20.9%) compared to the neutral pattern (18.6%), to the global bias-induced pattern (10.4%) and even to the local bias-induced pattern (16.3%), $F_{(N = 86, df = 3)} = 7.56$, $p < .05$. However, considered separately, only the difference between the global bias-

induced pattern and the competition-induced pattern was significant, $T_{(N=86)} = 24$, $Z = 2.04$, $p < .05$.

The *integrated responses* depicted by Figure 40C, showed no significant effect of age. The differences as a function of patterns were not significant (all $ps > .10$), except in children aged 11-12 years of age, $F_{(N=23, df=3)} = 8.57$, $p < .05$. Children at these ages produced more integrated responses when they were shown with the local bias-induced pattern (30.4%) than the global bias-induced pattern (26.1%), the neutral pattern (17.4%) and the competition-induced pattern (13%).

Figure 40D illustrated the *undifferentiated/syncretic responses* in function of age. No significant results were found, whether they concerned age or patterns (all $ps > .10$). The percentage of these responses remained low across ages and patterns (5.5%).

2. Analysis as a function of IQ

Figure 41 described the frequency of the drawing responses as a function of IQ.

Figure 41. *Percentage of responses in the drawing task by IQs*

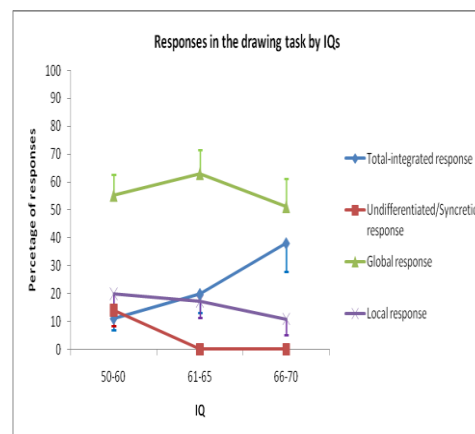


Figure 41 illustrated the frequency of total-integrated responses, syncretic responses, global responses and local responses as a function of IQ. Although the total-integrated responses seemed to increase in the higher IQ-group, no significant results supported this outcome. A significant IQ effect was only found for the syncretic responses, $H_{(2, N=86)} = 9.73$, $p < .01$, the lower IQ-group performing more frequently these responses (14%) than the other groups, since they disappeared with IQ increasing.

The global responses still dominated (56.7%) and they showed significant differences with the other responses, $F_{(N=86, df=3)} = 54.42$, $p < .01$. They were more frequent than the local responses, $T_{(N=86)} = 307.5$, $Z = 4.89$, $p < .01$, the integrated responses, $T_{(N=86)} = 694.5$,

$Z = 3.85$, $p < .01$ and the syncretic responses, $T_{(N = 86)} = 147.5$, $Z = 5.73$, $p < .01$. Figure 42 illustrated these data as a function of pattern.

Figure 42. Percentages of responses as a function of pattern and IQ in the drawing task

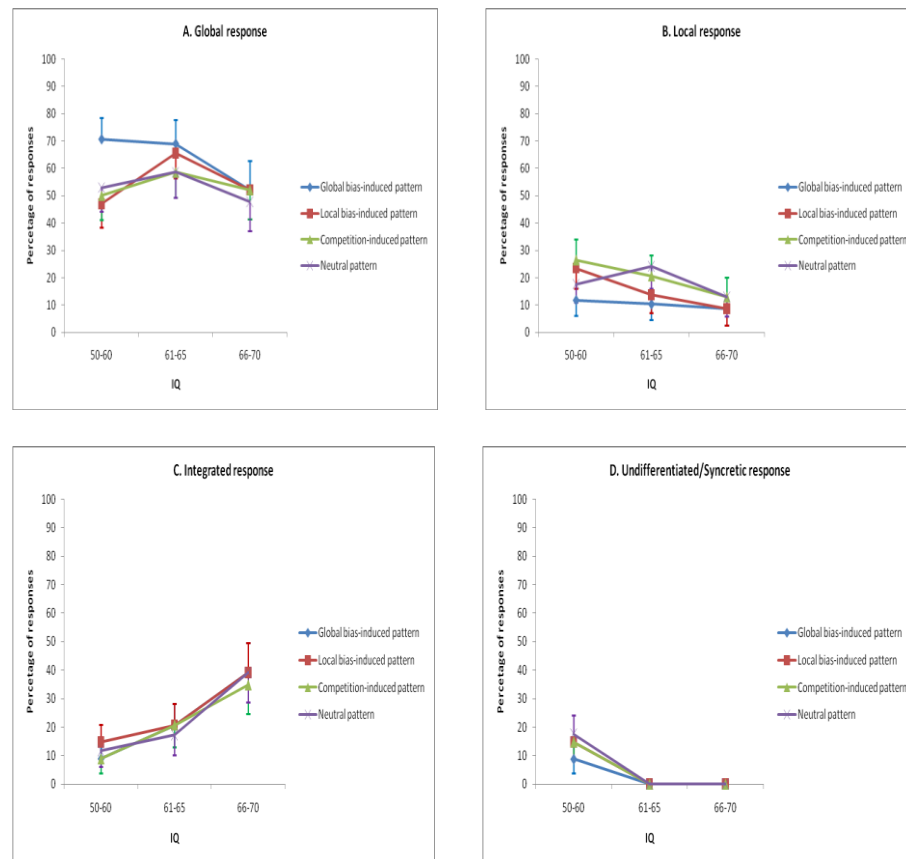


Figure 42A revealed that the global responses showed high percentages across all patterns (56.7%), but significant differences as a result of the patterns shown to children was found, $F_{(N = 86, df = 3)} = 15.43$, $p < .01$. The global bias-induced pattern elicited more global responses (65.1%) than the local bias-induced pattern (54.6%), $T_{(N = 86)} = 6$, $Z = 2.4$, $p < .05$. This difference was mainly found in the lower IQ-group, $T_{(N = 34)} = 0$, $Z = 2.52$, $p < .05$, where the global responses attained 70.6% with the global bias-induced pattern and 47.05% with the local bias-induced pattern. No effect of IQ yielded significant results ($ps > .10$).

Figure 42B illustrated the *local responses*. An effect of pattern was obtained, $F_{(N = 86, df = 3)} = 7.56$, $p < .05$. Surprisingly, the local responses were more induced by the competition pattern (20.9%), followed by the neutral pattern (18.6%) and afterwards by the local bias-induced figure (16.3%). No other significant results were found (all $ps > .10$).

The *integrated responses* as a function of pattern were shown in Figure 42C. Significant effects of IQ were found for almost all patterns. Integrated responses elicited by

the global bias-induced pattern showed a significant effect of IQ, $H_{(2, N = 86)} = 7.52, p < .05$, with children in the higher IQ-group producing more integrated responses (39.1%) than the children in the lower IQ-group (8.8%). A significant effect of IQ was also found for the competition-induced pattern, $H_{(2, N = 86)} = 5.578, p < .05$, and for the neutral pattern, $H_{(2, N = 86)} = 6.49, p < .05$ where again children in the higher IQ-group produced more integrated responses than the children in the lower IQ-group. No differences between patterns appeared (all $ps > .10$), which means that the use of meaningful or non-meaningful patterns might not affect the integration of local and global processing in the children's drawing.

Figure 42D represents the *syncretic responses* as a function of patterns. No significant effects of pattern were found (all $ps > .10$) but a significant effect of IQ was found except for the responses elicited by the global bias-induced pattern. Syncretic responses elicited by the competition-induced pattern and by the local bias-induced pattern, showed significant result, $H_{(2, N = 86)} = 8.02, p < .05$, where none of the children in the higher IQ-group produced syncretic responses, while 14.7% of children in the lower IQ-group performed these responses. Syncretic responses elicited by the neutral pattern also showed significant result, $H_{(2, N = 86)} = 9.75, p < .01$, where 17.64% children in the lower IQ-group produced syncretic responses (17.64%) and none of the children in the higher IQ-group produced it.

Discussion

The aim of the study was to analyze spatial analysis of hierarchical meaningful stimuli in children with MR using a naming task and a drawing task. Previous studies with meaningful stimuli showed that objects with meaning elicited an automatic identification process and promoted a global/local bias depending on the level at which the meaning was affected. Many studies in global/local processing that involved children with mental retardation showed contradictory results (Birhle, et al., 1989; Nakamura et al., 2009, Bellugi et al., 1990; Bellugi et al., 2000). By using hierarchical meaningful stimuli in a drawing task, we aimed to investigate whether meaning would interfere with the global/local processing in children with MR.

Four patterns were utilized in this study. The results showed that the global responses dominated largely, not only for the global bias-induced pattern, but also for the other patterns presented in the study. Even when global processing was clearly not enhanced by the pattern (e.g. with the local bias-induced pattern), the global responses were still dominating. This result fits with other findings, showing that children with mental retardation performed better in drawing the global shape than the local elements (Birhle, 1989; Bellugi et al., 1990; Bellugi et al., 2000).

In our experiment, age showed no effect in the naming task, neither in the drawing task of meaningful hierarchical patterns. This result could be well understood since the psychological development of children with mental retardation is more based on their mental age rather than on chronological age as used in this study. On the other hand, IQ was found significant in the production of non-integrated responses in the naming task and in the production of undifferentiated/syncretic responses in the drawing task, these responses being less frequent in the higher IQ-group than in the lower IQ-group. IQ also appeared significant in the production of total-integrated responses (naming-task) and integrated responses (drawing-task), where the integrated responses were more produced in the higher IQ-group. These results are coherent with other findings concerning the involvement of cognitive mechanisms in the perceptual analysis (Poirel et al, 2008; Singh & O'Boyle, 2004)

Although the global responses dominated the childrens' responses as mentioned before, our study found pattern's effects on the production of global and local responses. The global bias-induced pattern and the neutral pattern elicited more global responses, both in the naming task and drawing task, while the local responses were more elicited by the local bias-induced pattern and the competition-induced figure. In the drawing task, the competition-induced pattern elicited more local responses than the local bias-induced pattern. This result supports the fact that local interference was manifest, because interference of local elements with the global pattern was evidenced.

These findings are coherent with the work by Poirel et al (2006,2008) who suggested that meaningful objects could elicit global or local preference depending on the level at which they were assigned. Global preference occurred when the hierarchical pattern involved meaningful objects at the global level (this corresponds to the global bias-induced pattern and competition-induced pattern in our study) or when the pattern consisted of non-meaningful objects at both the global level and local level (corresponding to the neutral pattern in this study). On the other hand, local preference occurred when the meaningful objects were designed as local components (corresponding to the local bias-induced pattern and competition-induced pattern in our study).

CHAPTER 5. Global and Local Processing in Early Blind Children in a Naming and Drawing Task²

Introduction

Much of the research conducted in the domain of haptic perception has compared normal sighted, late blind, and early blind individuals in order to reveal the role of visual experience and visual imagery in haptic perception (e.g., D'Angiulli & Kennedy, 2001; Norman, Norman, Clayton, Lianekhammy, & Zielke, 2004; Dulin & Serrière, 2009). These studies have concentrated on comparing behavioral performances –for instance, naming pictures in raised-line drawings (Heller, 2002; Heller, McCarthy, & Clark, 2005)- as well as on comparative approaches to the neural substrates (Streri, Dion, & Mertz, 1996; James, Kim, & Fisher, 2007) or comparisons of contextual or individual effects, such as gender effects (Vecchi, 2001; Zuidhoek, Kappers, & Postma, 2007). Another interesting issue in the comparison between haptic and visual perception relates to the respective roles of global and local processing (Garner, 1974; Cook & Odom, 1988). Berger and Hatwell (1993) showed that analytical strategies predominate over holistic strategies in haptic perception. Developmental trends were also examined by Berger and Hatwell (1996) whose results contradicted those obtained in visual studies. In visual perception, access to the local dimensional structure takes longer and demands more attention than access to the global structure and, consequently, occurs later in the course of information processing. In haptic perception, in contrast, access to the global structure of the object should occur at a later stage of processing. Indeed, the sequential local exploratory movements prevent blind people from accessing global information, which therefore needs to be mentally reconstructed later by combining and integrating the precise information gathered locally. This idea that global processing develops later than local processing in haptic perception has found support in the work of Lakatos and Marks (1999) who reported that the ability to distinguish between 3D objects was increasingly based on local features as the exploration time decreased. Consequently, at the developmental level, younger children should exhibit a local processing bias in haptic perception, whereas a global bias should develop at older ages, a prediction that has received support from a number of studies (Berger & Hatwell, 1996; Schellingerhout, Smitsman, & Cox, 2005; Streri & Féron, 2005). To our knowledge, no previous developmental study has as yet addressed this issue in blind individuals.

² This chapter has been submitted for publication in *Child Development*. We reproduced most part of this paper here.

Furthermore, contradictory findings were reported by Norman et al. (2004) who argued that both touch and vision are sensitive to an object's global or overall shape. Pinneau and Streri (1990) found that 5-month-old infants are able to process haptically both the contour of an object and its local features. In this study, the children seemed to prefer to use the right hand (left hemisphere control) to discriminate features or local elements and the left hand (right hemisphere control) for the global contour. Thus, the extent to which haptic perception can inform individuals about both the global structure and the local organization of an object is still uncertain.

The aim of the present study was to investigate this issue in haptic perception in blind children by using hierarchical patterns of the type initially proposed by Navon (1977). Many researchers have used hierarchical patterns in order to study visual perception in both adults (e.g., Navon & Norman, 1983; Kimchi, 1988; Kramer, Ellenberg, Leonard, & Share, 1996; Love, Rouders, & Wisniewski, 1999; Lamb & Yund, 2000; Davidoff, Fonteneau, & Fagot, 2008) and children (e.g., Dukette & Stiles, 1996; Tada & Stiles, 1996; Burack, Enns, Iarocci, & Randolph, 2000; Kimchi, Hadad, Behrmann, & Palmer, 2005; Vinter, Puspitawati, & Witt, 2010). However, to our knowledge, only one study has focused on the haptic perception of hierarchical patterns in early-blind (EB) and late-blind (LB) participants (Heller & Clyburn, 1993). These authors employed two types of hierarchical stimuli, i.e. large Braille patterns (e.g., "R") made up of smaller standard-size Braille letters (e.g., "c"s) and large geometrical forms made of embossed dots. The participants were asked to name the explored shapes. The results obtained with the compound Braille stimuli showed that the LB and EB adults mainly gave local responses, although these responses were less frequent in LB (72.5%) than in EB participants (93.8%). LB participants processed information both locally and globally in 25% of cases, whereas none of the EB individuals did so. With the embossed geometrical patterns made of dots, the LB individuals primarily produced local responses (55.5%) and gave global responses at only a lower level (22.2%). By contrast, the EB individuals produced more global (50%) than local responses (27.7%), while blindfolded sighted participants produced integrated (both global and local) responses (61.1%), followed by global (16.6%) and local responses (11.1%). This study demonstrated the interference produced during a tactile Braille reading experience in EB individuals who had been asked to explore spatial patterns. It also revealed the important role played by the material given to blind participants in enhancing either local or global processing. However, only adults were tested and the question remains as to whether EB children also produce predominantly global responses when required to name hierarchical geometrical patterns. We considered this to be quite unlikely, considering that the haptic system attributes a greater weight to local than global features during the initial steps of processing (Lakatos & Marks, 1999).

The present study is the first to investigate the issue of local and global processing using tactile versions of Navon figures in a large corpus of EB children. We employed consistent and inconsistent geometrical hierarchical stimuli in order to reveal potential interference effects between the two types of processing, as has been observed in some studies dealing with visual perception (Navon, 1977; Martin, 1979; Kimchi, 1988, 1992; Mondloch, Geldart, Maurer, & de Schonen, 2003; Vinter et al, 2010). Indeed, the use of inconsistent patterns enabled Vinter et al. (2010) to observe local-to-global interference in young sighted children in a pattern similarity judgment task in which these young children exhibited a clear local processing dominance. Thus, presenting inconsistent patterns should enable us to observe whether EB children manifest interference effects in their haptic perception in the same way that sighted children do in visual perception.

In order to investigate in depth the capacity of blind people to process information locally and globally, we used both a naming task, as in Heller and Clyburn (1993), and a drawing task. During haptic perception, humans base their classification of an object on its various parts (Lederman & Klatzky, 1990, 1993; Klatzky, Lederman, & Mankinen, 2005; Vinter & Chartrel, 2008). Haptic classification is initially based on separate dimensional features, thus indicating analytical processing, before these local features are subsequently integrated during a global processing stage (Berger & Hatwell, 1993, 1996). We therefore expected children in the younger age groups to produce primarily local responses in the naming task whereas the older children should produce either more global responses, as can be predicted from the Heller and Clyburn's results, or more integrated responses. A drawing task, which is associated with considerable planning and motor requirements (van Sommers, 1989), was used to reveal the extent to which the children were able to coordinate a global and a local analysis of the patterns. Children may indeed attend to these two components without, however, being able to coordinate them (Dukette & Stiles, 1996; Vinter & Marot, 2007; Vinter et al., 2010). The ability of blind people to draw was reported in 1939 when Löwenfeld explored creativity in blind children. This ability was studied in more detail by Kennedy and his colleagues (D'Angiulli, Kennedy, & Heller, 1998, Kennedy, 2003; Kennedy & Juricevic, 2003, D'Angiulli, Miller, & Callaghan, 2008), who demonstrated that congenitally blind individuals are able to produce contour line drawings that capture the global shape of models. However, Vinter, Fernandes and Claudet (2009) reported that in around half of the drawings of familiar objects collected from EB children aged between 6 and 14 years, the elements making up the whole depicted object were drawn in a disconnected or juxtaposed way. This may indicate that blind individuals experience a specific difficulty in integrating local elements to produce a global shape. We therefore expected young blind children to mainly draw the local features of the patterns since only late in childhood would they be able to integrate local and global information in their drawings. Finally, since gender

may play a significant role in haptic perception in blind individuals (Vecchi, 2001), we decided to include, as far as this was possible, an equal number of EB boys and girls. Vecchi (2001) showed that blind females tended to develop less efficient strategies than blind males when active processing was required in a complex task. This suggests that blind females might process information differently from males when confronted with inconsistent hierarchical patterns.



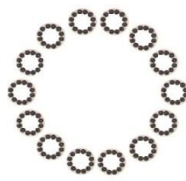


As revealed by the Heller and Clyburn study (1993), it is very likely that the material used to build tactile versions of geometrical Navon figures greatly affects blind people's ability to identify local or global components. We therefore ran a series of preliminary studies in order to test different materials. The results of these pilot studies are worth reporting because they provide important information about how to build tactile versions of Navon figures, and also because they can account for some of the differences obtained in our main experiment as well as in the Heller and Clyburn study (1993).

Pilot Studies

The stimuli tested in the *first preliminary experiment* were designed using Braille characters that formed squares or circles as local elements. As can be seen in Figure 43A, the standard-size Braille letters f, d, j and h were combined to form square local elements, while Figure 43B illustrates how the Braille letters i, c, e, e, c, i were combined to form circular local elements. There were 12 local elements in the overall global shape which was printed with a Braille printer so that the size and the space between elements were standard in the same way as in Braille text. The length of the sides of the square local elements was 1 cm x 1.25 cm (6.25 cm x 7.25 cm for the global shape). The diameter of the circular local elements was 1.5 cm (10 cm for the global shape). Thirty EB children aged between 6 and 16 years participated in this first preliminary study. There were 14 girls (mean age = 11.14 yrs, SD = 3.9) and 16 boys (mean age = 11.42 yrs, SD = 3.3). All the children involved in the pilot studies came from the same institutions and presented the same types of etiologies as those participating in the main experiment (see the method section). The children were asked to accurately explore the patterns in order to name them. The results showed that all the participants were puzzled by the patterns. Most of them (93.3%) perceived the Braille characters (and in particular the combination of f, d, j and h), but none of them recognized the global form or the local shapes. They therefore recognized the Braille material and used exploratory Braille reading procedures just as they do when reading Braille. Furthermore, because of the constraints linked to the use of a Braille printer, the density of elements was not high in these patterns. This may have reinforced local processing, although the current

literature is mute with regard to the possible role of elements density in haptic perception of Navon's figures.

Figure 43. *Examples of stimuli in the pilot studies*

		
A. Stimuli made of the combination of Braille-letters f, d, j, h at the local level.	B. Stimuli made of the combination of Braille letters i, c, e, e, c, i, at the local level.	C. Stimuli made of embossed dot-patterns at the local level.
		
D. Stimuli made of embossed line-pattern at the local level.		E. Stimuli made of embossed block-patterns at the local level.

The *second preliminary study* used shapes made of embossed dots as described in the Heller and Clyburn study (1993). The local elements used as stimuli had a diameter or side length of 1 cm and were made up of small dots as illustrated in Figure 43C. The diameter or side length of the global shape was 6 cm. The density of elements was increased in comparison with the previous patterns. The square global shape consisted of 16 local elements and the circular global shape of 14 local elements. The same participants as in the first preliminary study were asked to identify the shapes three weeks after the previous pilot study. 62.5% of them failed to identify the shapes (either local or global) because of a difficulty in perceiving an overall organization on the basis of a set of dots. 22.5% of the participants detected the global shape by perceiving the outline of the figure, 5% identified the local shapes and 10% identified both components.

In the *third preliminary study*, the thermoformed patterns were of the same size and density as in the second study, but the dots were replaced by lines. The stimuli are illustrated in Figure 43D. A number of studies of haptic perception have shown that blind children explore the contours of 2D patterns in order to perceive shape (D'Angiulli et al., 1998; Heller et al., 2005; Lederman, Klatzky, Rennert-May, Lee, Ng, & Hamilton, 2008) and a line configuration should enhance contour exploration. Thirty EB children, aged between 6 and 16

years, took part in this third pilot study: 15 boys (mean age = 10.64 yrs, SD = 3.4) and 15 girls (mean age = 11.85, SD = 3.5). As expected, performance was better in this study: 37.5% of the participants perceived both components in the patterns, 24.5% identified the local shapes, while 15% correctly identified the global shape. Nevertheless, 23.3% still had difficulty in identifying the shapes.

Since there were a large number of errors in this third preliminary experiment, we decided to use a different design after listening to the participants' accounts in the debriefing session during which they expressed the difficulties they experienced in perceiving a coherent shape on the basis of lines interspersed with blank spaces. This finding mirrors the observation made by Overvliet, Mayer, Smeets and Brenner (2008) that haptic searches are more efficient when the stimuli are interpreted as consisting of fewer items. Consequently, in the *fourth preliminary study*, the local elements consisted of block patterns instead of lines in an attempt to reinforce the impression that the local elements constituted complete entities (see Figure 1E). Another group of 30 blind children aged 6 to 16 years participated in the fourth preliminary study, 14 girls (mean age = 12.02, SD = 3.22) and 16 boys (mean age = 11.46, SD = 2.4). The results revealed that only 2.6% of them gave erroneous identification responses, 45% identified the two components, 18.3% the global shape only and 34.2% the local elements only. This design using thermoformed block patterns was selected for use in the main experiment since it appeared to be the one best suited to the haptic sensitivity of EB children.

Method

Participants.

One hundred and ten blind children aged 6 to 18 years (50 girls, 60 boys) participated in the experiment. They were totally blind or with minimal light perception (OMS categories: 4 and 5) from birth or early infancy under 14 month-age. They were divided into five age groups (see table 9). None of them participated in any earlier preliminary studies.

Table 9. *Age distribution of EB participants in the naming task*

No	Age group	<i>N</i>	<i>M / F</i>	<i>Mean</i>	<i>SD</i>
1	6-8	15	10 / 5	7.5	0.88
2	9-10	23	7 / 16	9.11	0.47
3	11-12	20	12 / 8	11.11	0.53
4	13-15	24	16 / 8	14.4	0.93
5	16-18	28	15 / 13	17.6	0.88
Total		110	60 / 50		

Some of the children ($N = 17$) refused to draw the patterns because they did not feel able to perform this task and wanted to avoid being placed in a difficult situation. The number of participants who performed the drawing task was consequently lower than that reported earlier. Ninety-three children aged between 6 and 18 years (40 girls, 53 boys) completed the drawing task. They were also divided into five age groups (see table 10).

Table 10. *Age distribution of EB participants who completed test performance in the drawing task.*

No	Age group	<i>N</i>	<i>M / F</i>	<i>Mean</i>	<i>SD</i>
1	6-8	12	8 / 4	7.6	0.76
2	9-10	15	4 / 11	9.11	0.50
3	11-12	16	11 / 5	12.0	0.51
4	13-15	22	15 / 7	14.4	0.91
5	16-18	28	15 / 13	17.6	0.88
Total		93	53 / 40		

None of these children performed drawing activities very frequently: around 20% of them drew on an occasional or regular basis while 80% drew only rarely or infrequently. The youngest children (6-8 years of age) were learning Braille, while those in the other age groups regularly practiced Braille reading and writing.

All the participants were attending special schools for blind and visually impaired children in six large cities in Indonesia (Jakarta, Bandung, Cimahi, Yogyakarta, Klaten and Solo). None of them presented any associated disorders of relevance for our study, in particular psychiatric, cognitive or neurological disorders. Indeed, they were all enrolled in the school grade that corresponded to their age (none of them were educationally advanced or retarded). Their blindness was due to congenital glaucoma, congenital cataract, Leber's congenital amaurosis, retrolental fibroplasia, retinoblastoma, microphthalmia, optic nerve atrophy, glioma, or anophthalmia. Most of the participants came from families with a medium or low socioeconomic status. However, all the children from low socioeconomic status families were living in school-organized hostels rather than with their families. The schools which took part in the study were supported either by the Ministry of Social Services in Indonesia or by other social organizations. Informed written consent was obtained from the parents as well as from the directors of the hostels in the case of the children who lived there. The experiment was conducted in accordance with the tenets of the World Medical Association Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects.

Material.

Four hierarchical patterns printed as block patterns using thermoformed shapes were employed (see Figure 1E) for the naming and drawing tasks. The consistent stimuli were a big square made up of small squares and a big circle made up of small circles. The inconsistent stimuli were a big square made up of small circles and a big circle made up of small squares. The patterns were printed individually on A5 format cards. The length of the sides of the square local elements was 1 cm, and the length of the side of the global shape was 6 cm. The diameter of the circular local elements was 1 cm and that of the global shape was 6 cm. The patterns consisted of 14 local circles and 16 local squares, respectively.

In the drawing task, the children were given a raised-line drawing kit. The drawings were produced using ballpoint pen on plastic sheets (21 cm x 14.7 cm) placed on a rubberized board. The pressure of the ballpoint pen on the plastic sheet produced a raised line, thus making it possible to provide haptic feedback during drawing execution.

Procedure.

The experiment began with an initial familiarization phase. There were 4 familiarization stimuli (thermoformed shapes) which consisted of one big circle of 6 cm in diameter, one big square with a side length of 6 cm, 5 randomly arranged small circles with a diameter of 1 cm and 5 small squares with a side length of 1 cm, also arranged randomly. The children were asked to name the shape of the explored patterns and, during the second part of the familiarization phase, draw them as accurately as possible using the raised-line drawing kit. Guidance was given by the experimenter if needed (guidance in moving the pen during drawing, verbal guidance during the exploration and also the naming of the shape, especially for the youngest children). During this familiarization phase, the experimenter made sure that the children named the patterns of 6 cm diameter/side length “big” and those of 1 cm diameter/side length “small”. The experimenter allowed the children to practice drawing circles and squares if they were not satisfied with their performance. It was during this familiarization phase that the experimenter identified the children who refused to draw the patterns. After the children had named and drawn the four stimuli once, the experimenter tested the participants’ understanding by presenting them with the four familiarization patterns again, in a random order, and asking them to name the shape that they perceived together with its size (i.e., big circle, small circles, big square, small squares). All the children succeeded in this examination phase. The familiarization phase took between 20 and 30 minutes. Each child was tested individually in a quiet classroom.

The experimental phase involved a very similar procedure. The children were comfortably seated at a table, and the experimenter placed the card on which the thermoformed pattern was printed on the table at a location aligned with the midline of each

child's body. The experimenter helped the children place their hands on the card and asked them to explore the shape of the printed pattern accurately in order to name it using precise terminology. The card was then removed and a second pattern was presented for naming. The patterns were presented in a random order. The responses given by the children were recorded by a second experimenter who could not see which pattern was placed in front of the child. The naming task was followed by an interval of 10-15 minutes. The experimenter informed the children who were willing to participate in the drawing task that they would now be required to explore patterns accurately in order to be able to draw them. They were not informed that the patterns were the same as those already explored in the naming task. The cards were again placed on the table one at a time for exploration. When the children said that they were ready to start drawing, the card was removed, the drawing material was placed at the same location, and the experimenter asked the children to reproduce the pattern as accurately as possible. The four stimuli were presented randomly, one at a time. No guidance or feedback was given during the naming or drawing task. The order of the two tasks was fixed. This was firstly due to the fact that during the familiarization phase, we had seen that fewer children were willing to draw than to name the patterns, and secondly because the literature reports that sketching explored line drawings facilitates their identification, thus suggesting that drawing could have a subsequent positive effect on naming (Witjntjes, van Lienen, Verstijnen, & Kappers, 2008).

Data Coding.

The verbal responses given by the children in the naming task were coded into four categories as described below:

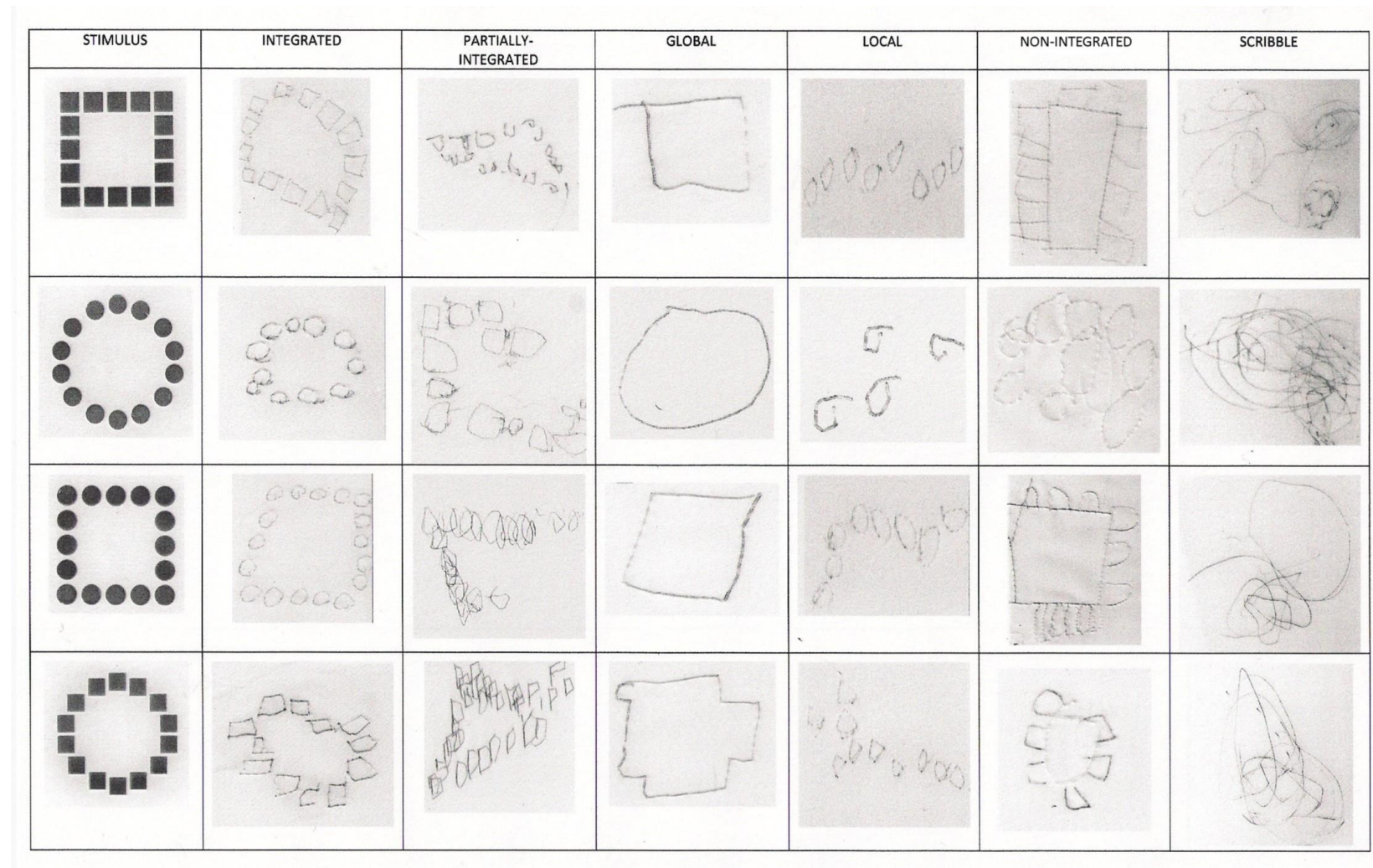
- ***Integrated Response:*** The children correctly identified both the global and local shapes and their integration, stating that the pattern was a big square made up of small squares/circles, or a big circle made up of small circles/squares.
- ***Global Response:*** The children correctly identified the global shape but did not mention or describe the local elements. Once the response was provided, the experimenter systematically asked “is there anything else you can perceive in this pattern?”. When the identification response was global, some of the children said that there was a hole or a space inside the square/circle, whereas others did not report perceiving anything else. When the children did not spontaneously specify the size of the shape they perceived, the experimenter systematically asked them: “can you tell me about the size of the square/circle?”. The response was considered global when the children only mentioned a big square or circle, often accompanied by finger movements tracing the outline of the global shape.

- **Local Response:** The children were able to name the local elements without noticing any other shape resulting from the arrangement of these local elements. We used the same process to categorize responses as local as is described above for the global responses. The response was considered local when the children only reported perceiving small circles or small squares.
- **Erroneous Response:** In a very few cases, the children produced erroneous responses. This response category was too rare to be analyzed further. In the case of consistent patterns, 4 children (one of 6 years of age, 1 aged 9 years, 2 aged 10 years) identified small squares even though the pattern contained small circles or, in contrast, small circles when only small squares were present. In the case of inconsistent patterns, 2 children (1 of 9 years of age, 1 aged 10 years) named a big circle after being presented with a big square made up of small circles, or a big square after exploring a big circle made up of small squares. If such errors had occurred more frequently it would have been interesting to analyze them because they could reveal a phenomenon of diffusion from the local to the global level, as reported in Vinter et al. (2010).

The results in the drawing task were sorted into 6 categories as described below and illustrated in Figure 44. Two judges coded the drawings independently. The percentages agreement between them was 89%. Disagreements were settled before data analysis.

- **Integrated Response.** The children drew the overall global shape and the local elements in a correctly integrated response. The sizes, number of elements, regularity of the distance between elements, accuracy of the angles, were not coded, and neither was the accuracy of the global or local shapes.
- **Partially Integrated Response.** The local elements, partially integrated with the global shape, were present in the drawing. The global shape was frequently left open, or only parts of it were drawn. The local and global shapes were generally greatly distorted.
- **Global Response.** The global shape was correctly reproduced as a continuous line and no local elements were drawn. The size of the shape was unambiguously big, when compared to the size of the patterns drawn by the children during the familiarization phase.
- **Local Response.** The children reproduced a series of small circles or small squares and the overall global shape was absent. The local elements were either randomly arranged or sometimes drawn in lines. There were always at least three elements and these were clearly small in size when compared to the drawings produced by the children during familiarization.
- **Non-integrated Response.** The local elements were drawn juxtaposed with or superimposed on the global shape.
- **Scribbled Response.** The drawings were simply scribbled.

Figure 44. *Examples of children's drawing based on the categorization in data coding*



Results

Non-parametric tests were used for the data analysis because homoscedasticity did not apply in most cases. The Kruskal-Wallis test (H value) was employed to test overall age differences, the Mann-Whitney test (U value) to test sex or age differences between two groups, and the Wilcoxon signed-rank test (T value) to test differences relating to pattern consistency.

A. Results from the naming task.

Figure 45 indicates the frequencies of integrated, global and local naming responses as a function of age and pattern consistency. As shown in Figure 45A, the number of *integrated responses* varied significantly across ages, $H_{(4, N=110)} = 30.1$, $p < .01$, becoming more frequent with increasing age. From 23% (SD = 37) at 6-8 years of age, the number of such responses reached 48% (SD = 43) at 13-15 years of age and represented 81% (SD = 30) of the responses given by the oldest adolescents. The transition that occurs between 9-10 and 13-15 years of age reached significance, $U = 180.5$, $n_1 = 23$, $n_2 = 24$, $p < .05$. Boys produced integrated responses more often ($M = 54\%$, $SD = 44$) than girls ($M = 37\%$, $SD = 42$), $U = 1179$, $n_1 = 50$, $n_2 = 60$, $p < .05$, and this gender difference was more pronounced in the case of inconsistent patterns ($p = .03$) than consistent patterns ($p = .07$). No significant effect of pattern consistency appeared, $T_{(N=110)} = 192$, $p > .50$.

Figure 45. Percentage of responses in the naming task as a function of age and consistency

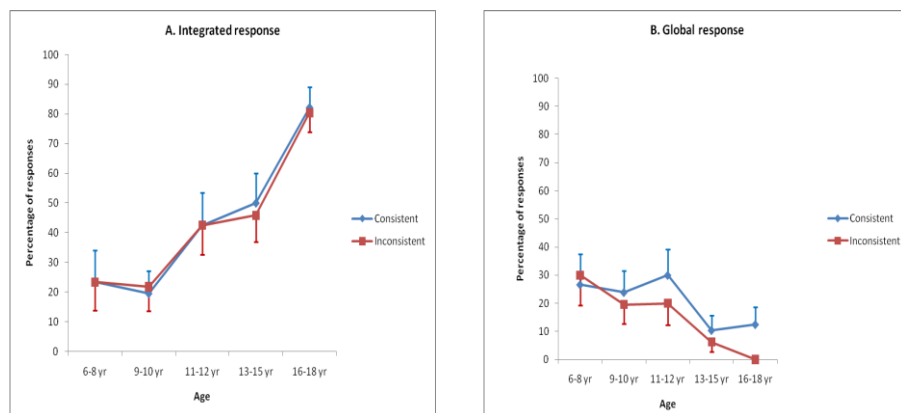
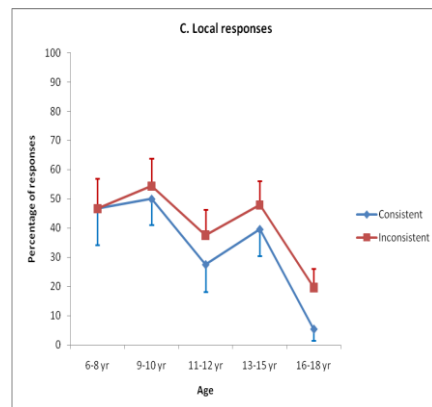


Figure 45. (continued)



Significant variations in the frequency of *global responses* across ages were observed, as is illustrated in Figure 45B, $H_{(4, N=110)} = 10.7$, $p < .05$. Around 28% (SD = 38) of the 6-8 year-olds gave a global response and this percentage dropped to 8% (SD = 30) at 16-18 years of age. The decrease between 9-10 years and 13-15 years of age was significant, $U = 198.5$, $n_1 = 23$, $n_2 = 24$, $p < .05$. Overall, the children produced significantly fewer global responses when exposed to inconsistent patterns ($M = 12.4\%$, $SD = 27$) than to consistent figures ($M = 19.2\%$, $SD = 35$), $T_{(N=110, df=1)} = 136.5$, $p < .05$. However, when each age range is considered separately, this effect was significant only in the oldest adolescent group, $p = .05$.

Finally, variations as a function of age were also observed in the *local responses* as depicted in Figure 45C, $H_{(4, N=110)} = 18.9$, $p < .01$. Produced in around 47% (SD = 41) of cases at 6-8 years of age, they decreased progressively to represent only 12.5% (SD = 19) of the responses provided by the 16-18 year-olds. An effect of consistency that was just significant was found, $T_{(N=110, df=1)} = 365$, $p = .05$, with local responses being elicited more often by the inconsistent ($M = 40\%$, $SD = 41$) than by the consistent patterns ($M = 31.6\%$, $SD = 42$). Furthermore, the girls produced local naming responses ($M = 44.5\%$, $SD = 37$) more frequently than the boys ($M = 28.7\%$, $SD = 35$), $U = 1127$, $n_1 = 50$, $n_2 = 60$, $p < .05$. This was mainly due to the inconsistent patterns on which the girls responded locally in 50% of cases (SD = 42) and the boys in 31.6% (SD = 37), $U = 1148$, $n_1 = 50$, $n_2 = 60$, $p < .05$. However, the difference, although similar, failed to reach significance for the consistent patterns ($p = .09$).

Because there was quite a high level of variability within each age group, we also performed an analysis of the individual data and assigned each child to one of four profiles as a function of the proportions of different types of naming responses he or she produced: local dominant (75 to 100% local responses), global dominant (75 to 100% global responses), integrated dominant (75 to 100% integrated responses) and mixed profile (between 0 and 50%

local and/or global and/or integrated responses). Table 11 indicates the assignment of the EB children to these profiles as a function of their age.

Table 11. *Distribution of the profiles in the naming task*

Age group (yrs)	Local	Global	Integrated	Mixed profile	Total
6-8	7 (46,7%)	4 (26,6%)	3 (20%)	1 (6,7%)	15
9-10	10 (43,5%)	4 (17,4%)	4 (17,4%)	5 (21,7%)	23
11-12	5 (25%)	5 (25%)	8 (40%)	2 (20%)	20
13-15	8 (33,33%)	1 (4,2%)	11 (45,8%)	4 (16,66%)	24
16-18	0 (0%)	0 (0%)	21 (75%)	7 (25%)	28
Total	30	14	47	19	110

This table confirms the predominance of local processing in the youngest age groups. More children in the first two age groups (6 to 10 years of age) exhibited a local profile ($n = 17$) than an integrated profile ($n = 7$), $\chi^2_{(1)} = 6.1, p < .05$, or a global profile ($n = 8$), $\chi^2_{(1)} = 4.83, p < .05$. It was not until the period between 13 and 15 years of age that the integrated profile ($n = 11$) predominated over the global one ($n = 1$), $\chi^2_{(1)} = 11.1, p < .01$, and 16 to 18 years of age for the integrated profile ($n = 21$) to predominate over the local profile ($n = 0$), $\chi^2_{(1)} = 33.6, p < .01$.

B. Results from the drawing task.

Figure 46 presents the frequencies of occurrence of the different response categories obtained in the drawing task as a function of age and consistency.

Figure 46. *Percentages of responses in the drawing task as a function of age and consistency*

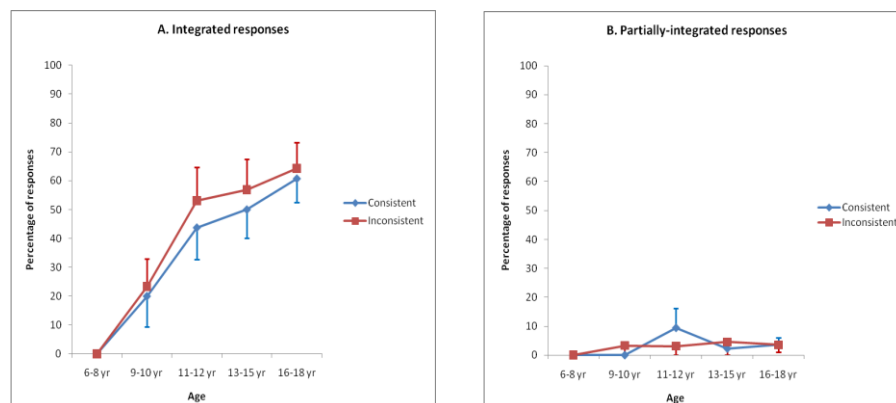
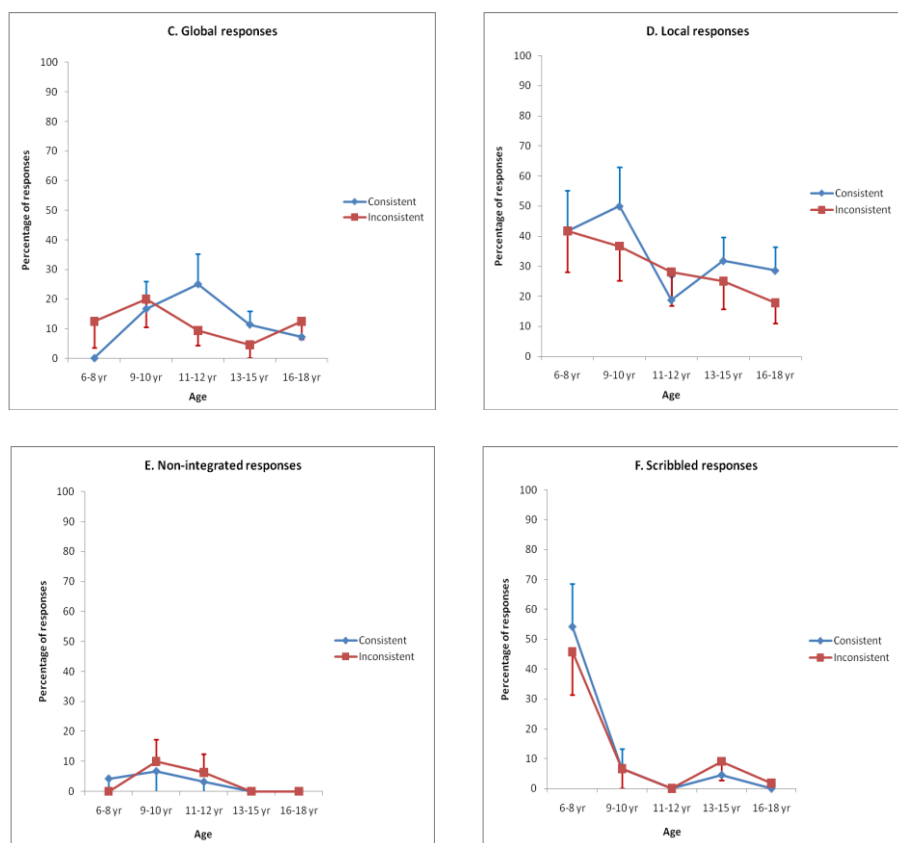


Figure 46. (continued)



Significant differences between ages were obtained for the *integrated responses* (Figure 46A), $H_{(4, N=93)} = 23.03, p < .01$. None of the 6-8 year-olds drew integrated patterns, while 48.4% (SD = 37) of the drawings produced by the 11-12 year-olds were integrated ($U = 24, n_1 = 12, n_2 = 16, p < .01$). This percentage then increased slowly to reach 62.5% (SD = 43) at 16-18 years of age. Although there was a slight but constant tendency across ages for inconsistent patterns to elicit integrated responses more frequently than consistent patterns, the consistency effect did not reach significance, $T_{(N=93)} = 77, p = .18$. The occurrences of *partially integrated responses* (Figure 46B) were, on average, very low ($M = 3.2\%$, $SD = 10$) and reached a maximum value of only 10% in the 11-12 year age group for the drawing of consistent patterns. They did not vary as a function of age, consistency or gender ($p_s > .60$).

The age-related change in the frequencies of *global responses* was more interesting as far as the consistent patterns are concerned (Figure 46C). This type of response increased significantly between 6-8 years (no occurrences) and 11-12 years of age ($U = 66, n_1 = 12, n_2 = 16, p < .05$), reaching 25% (SD = 40) in the latter group, before decreasing significantly up to 16-18 years of age ($M = 7.1\%$, $SD = 26$), $U = 172, n_1 = 16, n_2 = 28, p < .05$. In the case of inconsistent patterns, the age-related change in the global responses was much less clear,

although the overall production of these responses did not differ significantly from that of the consistent patterns, $p > .50$. No effect of gender was reported ($p > .60$).

Local responses (Figure 46D) were significantly more frequent ($M = 30.1\%$, $SD = 38$) than global ones ($M = 11.5\%$, $SD = 26$), $T_{(N=93)} = 244.5$, $p < .05$, especially in the youngest age group. Despite this, they did not vary significantly across ages, $H_{(4, N=93)} = 3.3$, $p = .50$. The level of local responses was still 23.2 % at 16-18 years of age ($SD = 35$). Their decrease between 6-8 years and 16-18 years of age in the presence of inconsistent patterns just failed to reach significance ($U = 120$, $n_1 = 12$, $n_2 = 28$, $p = .07$). The girls produced this type of drawing more often ($M = 45\%$, $SD = 39$) than the boys ($M = 18.9\%$, $SD = 33$), $U = 663$, $n_1 = 53$, $n_2 = 40$, $p < .01$, in response to both the consistent ($p = .01$) and the inconsistent ($p = .02$) patterns. No effect of consistency was found, $T_{(N=93)} = 115$, $p = .12$.

Non-integrated responses (Figure 46E) were produced only rarely ($M = 2.4\%$, $SD = 12$), reaching a peak value of only 8.3% ($SD = 26$) at 9-10 years of age. Age, consistency and gender all failed to induce any significant differences ($p_s > .20$).

Finally, the frequency of *scribbling responses* (Figure 46F) varied significantly as a function of age, $H_{(4, N=93)} = 36$, $p < .01$, being quite frequent at 6-8 years of age ($M = 50\%$, $SD = 46$) and then declining abruptly to reach a low level of occurrence at 9-10 years of age ($M = 6.7\%$, $SD = 25$), $U = 37.5$, $n_1 = 12$, $n_2 = 15$, $p < .05$. Boys produced more scribbles ($M = 15.1\%$, $SD = 34$) than girls ($M = 1.9\%$, $SD = 8.7$), as the significant gender effect shows, $U = 906.5$, $n_1 = 53$, $n_2 = 40$, $p < .05$. No other significant differences were found ($p > .20$).

The children were considered individually and assigned to one of 6 different profiles depending on their performance in the drawing task: scribbling dominant (we applied the same criteria as in the naming task, 75 to 100% of scribbling responses), local dominant, global dominant, integrated dominant, non-integrated dominant or mixed profile. The assignment of the children to these profiles is indicated in Table 12.

Table 12: *Distribution of the profiles in the drawing task*

Age group (yrs)	Scribbling	Local	Global	Integrated	Non- integrated	Mixed profile	Total
6-8	5 (41,6%)	5 (41,6%)	0 (0%)	0 (0%)	0 (0%)	2 (16.7%)	12
9-10	1 (6,66%)	6 (40%)	2 (13,33%)	3 (20%)	1 (6,66%)	2 (13,33%)	15
11-12	0 (0%)	4 (25%)	2 (12.5%)	6 (37.5%)	0 (0%)	4 (25%)	16
13-15	1 (4,54%)	5 (22.7%)	1 (4.54%)	11 (50%)	0 (0%)	4 (18.2%)	22
16-18	0 (0%)	6 (21.4%)	2 (7.1%)	16 (57.1%)	0 (0%)	4 (14.3%)	28
Total	7	26	7	36	1	16	93

In the same way as for the naming task, this table confirms that more of the children in the first two age groups exhibited local processing dominance ($n = 11$) than integrated

processing dominance ($n = 3$), $\chi^2_{(1)} = 7$, $p < .01$. The level of dominance of these two types of processing was reversed from 13-15 years of age onwards, $\chi^2_{(1)} = 3.54$, $p = .06$. The fact that only a small number of children exhibited a global dominance profile in the different age groups indicates that this response was quite infrequent.

Finally, we computed the Spearman-rank correlations between performance in the naming and drawing tasks. To do this, we limited the number of participants considered in the naming task to those who also drew the patterns. The 3 response categories that were common to both tasks were considered. The children who produced integrated, global or local responses in the naming task also tended to provide integrated ($r = .50$, $p < .01$), global ($r = .26$, $p < .05$) or local ($r = .29$, $p < .01$) responses in the drawing task.

Discussion

The aim of the present study was to build tactile versions of Navon's geometrical patterns in order to investigate the type of processing – local or global – that is predominant at different ages in EB children and the age at which these visually disabled children are able to integrate and coordinate the two types of information. To our knowledge, this study is the first to adopt a developmental approach to the assessment of local and global processing in EB children by using tactile Navon figures. We employed both a naming task, as in the Heller and Clyburn study (1993) investigating EB and LB adults, and a drawing task as used in a small number of studies involving sighted children (Dukette & Stiles, 2001; Lange-Küttner, 2000; Vinter et al., 2010) or children with mental retardation (Birhler, Bellugi, Delis, & Marks, 1989; Farran, Jarrold, & Gathercole, 2003; Porter & Coltheart, 2006). The results yielded by these two tasks were quite similar results across ages, as the significant inter-task correlations attest. This finding confirms the validity of the drawing task as a way of addressing this issue, even in blind individuals.

Indeed, the two tasks revealed that EB children mainly produced local responses at ages of between 6 and 10 years and that the proportion of local responses decreased with age. These findings were replicated when the data were analyzed at an individual level in which a predominant processing profile was assigned to each participant. The initial dominance of local processing appears to be consistent with the work conducted by Berger and Hatwell (1996), who concluded that dimensional local relations organize haptic perceptual classification in young sighted children. Similarly, Lakatos and Marks (1999) reported that blindfolded sighted adults, who were asked to judge whether two objects were the same or not, relied more heavily on local than on global features during the initial stages of haptic exploration. In a study of blind individuals, Heller and Clyburn (1993) showed that adults produced more local than global responses when required to name compound Braille stimuli.

Our study extended this investigation to EB children, and confirmed the initial dominance of local processing in haptic perception up to the age of around 10 years. It is worth pointing out that when young sighted children are required to perform the visual exploration of hierarchical patterns, they also display an initial bias toward local processing which, however, continues until only about 6 years of age (e.g., Poirel, Mellet, Houdé, & Pineau, 2008; Vinter et al., 2010). The protracted dominance of local processing in the development of EB children is probably due to the sequential nature of the exploratory manual movements that are used by blind people to process shapes and prevent fast access to the global shape. Access to the global shape of unknown patterns requires highly developed mental capabilities for the coordination and integration of information and these capabilities need time to develop.

In both the naming and the drawing task, the younger participants produced fewer global than local responses. However, the fact that the latter type of response was still present shows that young EB children can attend to both local and global information. At the age of about 11-12 years, the frequencies of the two types of responses were quite similar before decreasing in both tasks as the number of integrated responses increased. Unlike Heller and Clyburn (1993) who reported that EB adults named the global shape more often than the local elements when exploring embossed dot patterns, at no stage during our study did we observe a predominance of global over local responses. Furthermore, the older children tended to provide integrated rather than global responses in the naming task. These discrepancies between our study and that conducted by Heller and Clyburn are very probably due to the material used to build the tactile Navon patterns. Indeed, in our second pilot experiment in which we used material identical to that employed by Heller and Clyburn (1993), EB children again produced more global responses than local or integrated ones. The tactile versions of the Navon figures employed in the present experiment were probably more similar to their usual visual counterparts than those used in the Heller and Clyburn study (1993) or our first three pilot studies because they reinforce the impression that the local elements are complete entities and make it possible to interpret the tactile information as consisting of fewer items (Overvliet et al., 2008).

In line with the fact that the global shape is harder to access during haptic exploration our study confirms this ability emerges at a later stage of development. It is possible to argue that the greater difficulty in accessing the global shape of tactile images experienced by EB children is related to the way they explore the patterns. More specifically, the enclosure procedure could be beneficial to global shape processing, while the encoding of local shape information could be facilitated by the use of the contour-following procedure. However, Lakatos and Marks (1999) noted that neither contour-following nor enclosure were associated with a predominant emphasis on either local or global features when adults were required to judge whether two haptically explored patterns were identical or not. This observation might,

of course, be different in the case of children. However, our informal observations of how children explored the Navon figures point to the same conclusion since our participants always made use of enclosure and frequently had recourse to contour-following. This in no way means that the procedure adopted for haptic exploration is of little relevance for shape and object recognition, as has been clearly shown by Kalagher and Jones (2011) and D'Angiulli and Kennedy (2000, 2001). However, it does indicate that the enclosure and contour-following procedures, which are suitable for the extraction of the properties of a shape (Lederman & Klatzky, 1993), probably do not account for the dominance of one or other type of processing, in the same way that oculomotor activity is possibly not sufficient to account for local or global dominance in visual tasks. This suggests that the dominance of local over global processing in haptic perception in EB children is probably due more to the integrative steps involved in the processing of shapes and objects than to more peripheral information gathering activities.

Absent in the drawing task and present at a low level in the naming task at 6-8 years of age, the integrated responses increased with age. They became the predominant response category as of 11-12 years of age in both tasks, thus demonstrating that the difficulty in producing integrated responses was not due to specific graphic difficulties experienced by EB children. The short period of training provided during the familiarization phase was efficient enough to permit all the children who agreed to produce drawings to draw small and big circles and squares (although often with considerable distortions). Although there were very few non-integrated responses in which the local and global components were present but juxtaposed, it is interesting to note that these occurred primarily at 9-10 years of age and disappeared at 13-15 years of age. Young sighted children who were asked to copy similar geometrical Navon figures also primarily produced local or non-integrated responses before integrated responses became dominant at 6 years of age (Vinter et al., 2010). This suggests that the development of local and global processing generally proceeds in the same way in sighted and blind children and that there is a protracted period during which local processing dominates in blind children, with the result that they exhibit a developmental lag when the performances of the two populations are compared in a drawing task. The non-integrated drawings may indicate difficulties in the understanding of part-whole relationships as certain drawing studies have indicated (e.g., Tada & Stiles, 1996; Vinter & Marot, 2007). Indeed, a recent study assessing the tactile functioning of children with congenital blindness reported that items measuring the understanding of part-whole relationships were among those that these children found difficult to master (Withagen, Vervloed, Janssen, Knoors, & Verhoeven, 2010).

In the present experiment, the EB children had to name and draw consistent and inconsistent tactile Navon figures. A small number of significant effects relating to pattern

consistency were observed in the naming task only. Local responses were more frequent for inconsistent than consistent figures, while global responses occurred more frequently in the case of consistent than inconsistent patterns. These findings may illustrate the use of a hypothesis testing strategy as described by Alexander, Johnson and Schreiber (2002) in their study of haptic exploration in children aged 4-9 years. These authors reported that whereas children who had considerable knowledge of the explored object domain (dinosaurs) identified the objects correctly, they also made more errors associated with the use of a hypothesis testing strategy. Their identification of highly pertinent local features that they knew to be critical for the identification of a specific type of dinosaur sometimes led them to draw incorrect conclusions when asked to judge whether or not two dinosaurs were identical. Instead of fully exploring the two models, these children displayed a confirmatory bias based on the identification of distinctive local features. Perhaps the EB children in our study tended to make the assumption that the pattern was unique when they perceived that the local elements had the same shape as the global configuration. In contrast, when there was a mismatch between the local shapes and the global configuration, the assumption was in favor of the dominant local information. If this account is correct, it would suggest that the way pattern consistency is manipulated differs greatly between haptic and visual exploration. It is unlikely that interference effects would occur during haptic exploration, as they do in the visual mode, because of the extended timecourse of global information processing in the haptic mode. This would explain why we observed only a small number of erroneous responses in the drawing task when compared to a similar experiment run with sighted children (Vinter et al., 2010).

Finally, some differences between EB girls and boys were observed in the experiment. In both the naming and drawing tasks, the girls produced local responses more frequently than the boys. This result provides support for the findings reported by Steri et al. (1996) which suggest that girls process haptic information analytically and discriminate details, especially when employing the right hand. It is also consistent with developmental models that suggest that the left hemisphere is favored early in girls (Collucia, Iosue, & Brandimonte, 2007), as the left hemisphere has been found more efficient than the right one for local information processing (e.g., Lamb, Robertson, & Knight, 1989). Furthermore, in the naming task, the boys produced integrated responses more frequently than the girls. Vecchi (2001) found that blind males developed more efficient strategies than females when active processing was required in a complex task. The gender differences we observed might primarily be due to similar differences in information processing strategies, with the boys deploying more efficient strategies for the coordination of local and global information in response to the more complex patterns (the inconsistent patterns). However, they may also be due to more basic differences in haptic perception, given that Zuidhoek et al. (2007) found

that males performed better than females in a variety of tasks assessing the haptic perception of orientation. Defining more precisely what may underlie the gender differences observed in our experiment appears therefore delicate, and further research on this topic is needed for clarification. The only gender difference that is coherent with the overall literature was obtained in the drawing task, where the boys produced more scribbled drawings than the girls. Many studies have revealed that girls achieve better performances than boys in tasks requiring fine motor abilities (e.g., Fairweather, 1976; Kraft & Nickel, 1995).

In conclusion, it is important to recall that this experiment is the first to investigate how EB children process local and global information in tactile Navon figures. For this reason, we tested a large sample of children on the basis of two different tasks. Replications will be needed in order to confirm our main finding that the development of local and global processing seems to proceed in similar ways in sighted and EB children even though there is a protracted period during which local processing dominates in blind children.

GENERAL DISCUSSION & CONCLUSION

CHAPTER 6 : GENERAL DISCUSSION and CONCLUSION

The experiments that have been done in this study were aimed at understanding more comprehensively the characteristics of children's perception, through their way to process hierarchical patterns at a global and local level. These characteristics were revealed employing different stimuli, different tasks and involving typical and atypical children in order to examine which aspects marked the genuine milestones of children's development in processing hierarchical patterns, and how these milestones can be sensitive to contextual factors.

Since Navon (1977) introduced the concept of examining perceptual processes through hierarchical patterns more than thirty years ago, a lot of research has been done in this domain. The *global/local advantage* or *global/local precedence effect* refers to the availability of one level of information before the other level (most authors studied the global precedence effect because the global shape was generally found to be processed before the local elements). The *global/local interference effect* refers to the disturbances of the global shape or the local elements. Many results from previous studies suggested that the identification of the global shape did not interfere with the disturbances of the local elements, while the identification of the local elements was interfered by the identity of the global shape (*global interference effect*). These Navon's terms were developed by other authors who extended his work on global /local processing. One of them, commonly used, is *global/local preference* which refers to the tendency to prefer one level of processing than the other level. The term of *global/local processing bias* described the same phenomenon where the global processing bias refers to the preference for the whole pattern and local processing bias described the preference for detail-level information or preference for the local elements (Farran et al., 2003; Johnson, Blaha, Houpt, & Townsend, 2010).

Our studies did not only concern the process of perception but also involved the integration of the perceptual processes into the drawing ability. Studies on drawing behavior showed that changes during development result from changes in the mental representations used to plan behavior and in the capacity to manage part-whole relationships (Vinter, Picard & Fernandes, 2008). Although a drawing task may be more complex than a perceptual task as it needs additional requirements in terms of planning and motor demands (van Sommers, 1989), some studies confirmed that drawing hierarchical patterns constitutes a way to approaching how children perceive these patterns (Feeney & Stiles, 1996; Bouaziz & Magnan, 2007; Tada & Stiles, 1996; Dukette & Stiles, 1996).

However, these studies showed contradictory results because some authors suggested that the whole object is segmented into parts in a similar way both in perception and drawing

tasks (Feeney & Stiles, 1996), while some others stated that depending on the children's age, perceptual and drawing tasks may provide different results in terms of children's capacity to segment a whole pattern (Bouaziz & Magnan, 2007). Farran and Cole (2008) supported also this idea as their study proved that the cognitive demands of drawing and construction tasks led participants to correctly perceive an image before reproducing it part by part until a complete reproduction has been achieved, while the perceptual forced-choice task showed an opposite result, with children tending to process the pattern from global to local. This contradictory literature showed that it was worth including perceptual and drawing tasks in our thesis in order to achieve a more comprehensive understanding about children's spatial analysis of the hierarchical patterns.

In overall, we employed three kinds of tasks, which were a similarity judgment task, a naming task and a drawing task. The similarity judgment task of hierarchical patterns was first used by Kimchi & Palmer (1982). Goldmeier (1972) stated that similarity cannot always be defined as partial identity, neither as identity of relational proportions because similarity is often based on the singular whole qualities which determine the phenomenal appearance of a figure. Thus, the similarity judgment task can illustrate the tendency to global and local preference (as in the work of Farran and Cole, 2008) but is mute to the question of how one process can be integrated with the other. In order to apprehend the integration question, we introduced the drawing task that precisely necessitated that children combined a local and global analysis of the patterns, since drawing task required planned behavior with the capacity to manage part-whole relationships (Vinter et al, 2008). The naming task was more similar to the drawing task than to the similarity-judgment task following this line of reasoning. Porter and Coltheart (2006) used such a naming task to study global-local processing in atypical developing children. We also employed this task with the two populations of atypical children we have studied, children with mental retardation and blind children.

We suggest discussing our results in terms of *global/local preference* or *advantage*, *global/local interference* and *local-global integration* with regard to the effect of age, stimuli, duration and gender across typical and atypical developing children.

A. What about the age effect on local and global perception ?

Let's consider first the developmental trends evidenced in typically developing children. Previous studies suggested that age matters in the processing the hierarchical patterns, so children at various ages were involved in our experiments. Research with infants (between 3 to 13 months of age) analyzed haptic abilities (Streri, 2002), eye fixations (Colombo, Freeseaman, Coldren, & Frick, 1995; Stoecker, Colombo, Frickm, & Allen, 1998) and visual-evoked potentials (Norcia, Pei, Bonneh, Hou, Sampath, & Pettet, 2005). Face

stimuli were also used to reveal this global-local processing in babies (Schwarzer & Zauner, 2003). Research with children at older ages (from 3 to 14 years of age) utilized tasks more similar to the ones used with adults. Similarity judgment tasks (Neiworth, Gleichman, Olinick, & Lamp, 2006; Rondan et al., 2008; Poirel et al, 2008; Deruelle et al, 2006; Mondloch et al, 2003, Faran & Cole, 2008), orientation judgment tasks (Stiles, Delis, & Tada, 1991), divided and selective attention tasks (Plaisted et al.,1999; Porporino et al, 2004), naming or indicating tasks (Iarocci, Burack, Shore, & Mottron, 2006; Scherf, Behrman, Kimchi, & Luna, 2009; Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2000), matching forced choice tasks (Harrison & Stiles, 2009, De Lillo, Spinozzi, Truppa, & Naylor, 2005; Plaisted, Dobler, Bell, & Davis, 2006; Vinter et al, 2010) and drawing tasks (Stiles, Stern, Appelbaum, Nass, Trauner, & Hesselink, 2008; Rondan et al, 2008; Abreu, French, Cowell, & deSchonen, 2006; Faran & Cole, 2008; Vinter et al, 2010).

This body of research showed contradictory results. Some authors proposed that children at younger ages attended to local information more than children at older ages (Colombo et al., 1995; Kramer et al., 1996; Dukette & Stiles, 1996; Frick, Colombo, & Allen, 2000; Burack et al., 2000; Poirel et al., 2008) but some others showed the same global precedence effect as in adults (Stoecker, Colombo, Frick, & Allen, 1998; Mondloch et al., 2003) and still others proposed that children can attend to both the local and global level, depending on contextual and task factors, the integration between the two levels of analysis developing until late in adolescence (Kimchi et al., 2005; Schref et al., 2009). Our results showed that local and global processing co-exist first without integration, this period being accompanied by a dominance of local processing, and then when they start to be integrated, this is accompanied by a global dominance effect.

Only Experiments 1 and 2 with typically developing children included children as young as 3 years of age. Our results revealed that children at 3 years of age showed a dominance of local performance, both in the similarity judgment task and in the drawing task. These results confirmed that that local processing dominates the global one in young children (Dukette & Stiles, 1996; Kramer et al., 1996; Poirel et al., 2008). Interestingly, the local dominance period was associated with the demonstration of local to global interference, the erroneous global responses in the drawing task being largely the most frequent errors, and they occurred significantly more often with inconsistent figures. This association paralleled the one shown in adults of global dominance with global to local interference effects. However, if local processing dominated first, the drawing task showed that children as young as 3 years of age actually attended to both the global and local level, but these modes of spatial information processing operated independently, as if they did not refer to a unique entity, as shown by the high percentages of non-integrated responses. If we assume that global processing tends to rely on the right hemisphere and local processing on the left

hemisphere (e.g., Moses et al., 2002), this independent functioning may be a consequence of the still immature interhemispheric communication in the integration of visual information. It is indeed only at around 2 years of age that processing from the two hemispheres starts to be coordinated (Liegeois, Bentejac, & de Schonen, 2000).

After 3 years of age, an important change occurred as testified by the results obtained in the similarity judgment task with global processing preference emerging at 4 years of age and these responses increasing as children get older. It can be said that when children had to decide whether a compound figure bore more similarity with its global shape or with an arrangement made of its local elements, they tended to select more and more often the global shape and less and less often the local elements as age progressed. These tendencies were found across different stimuli (consistent vs inconsistent and simple vs complex), independently also to the duration of exposure of the targets. Note that the complexity of the figures tended to reinforce this global processing preference, as could be seen when the results from the two first experiments are compared with those of Experiments 3 and 4. Indeed, the patterns used in the two first experiments are even simpler than the so-called “simple” patterns employed in Experiments 3 and 4. And our results showed that global processing preference was on average higher in these two last experiments. The same trend emerged in the drawing task, since the global responses were produced at a quite high level in Experiment 3 when compared to Experiment 2. However, the tendency of the two levels of perceptual analysis to operate independently was still evidenced in children at 4 years of age, as revealed by the frame-part analysis in the drawing task (Experiment 3) that showed more part-absent and frame-absent responses at this age.

Note that this schema of two levels of analysis, independent, with the local level stronger in a first step (3-4 years), and then the global level increasing (4-5 yrs), may seem in contradiction with the results obtained in Experiment 3 (drawing task), concerning the frame-part analysis. Indeed these results suggest that the frame-correct analysis develops earlier and faster than the part-correct analysis. It is important to point out that these results cannot be compared directly to those obtained in the perceptual task. Drawing correctly the frame in Experiment 3 means drawing a square, while drawing correctly the parts means drawing crossed lines, obliques or triangles, that is figures more complex to reproduce. The sensitivity of part-correct analysis to the duration of exposure of the targets, and not of the frame-part analysis, is coherent with this suggestion of higher complexity of the former as compared to the later.

To continue with development, our results indicate that once global processing preference emerged (as revealed by the similarity judgment task), the integration between the two levels of perceptual analysis developed (as revealed by the drawing task). Indeed, in Experiment 1 and 3, the integrated responses, either correct or inaccurate, developed rapidly

between 4 and 5 years of age. At 5 years of age, children produced correct integrated responses in about 70% of the cases, and these responses characterized almost 100% of the drawing production at 9 years of age. Furthermore, none of these 9 years-old children displayed any more non-integrated responses or partial or absent responses. These developmental changes in the integration between the global and local processing were significantly confirmed across stimuli (consistent vs inconsistent, simple vs. complex).

Do these developmental trends also characterize the atypically developing children studied in our thesis? Of course, the comparison cannot be direct between these populations, mainly because only the drawing task was common to all studies. Instead of a similarity judgment task, relevant to reveal processing preferences, we adopted a naming task with the blind children and those with mental retardation. The naming task does not indicate directly processing preferences. It is closer to the drawing task, requiring integration between the two levels of processing, without the procedural constraints linked to drawing in se. Furthermore, we did not include children as young as 3 to 5 years of age in the blind study and the mental retardation study, thus limiting our comprehension of early development in these atypical populations.

Keeping in mind these limits, the answer to the question of knowing whether development proceeds similarly to what was observed in typically developing children is “yes” for what concerns the blind children, although large differences appeared with regard to the ages of the main milestones. We noted that local processing, enhanced by haptic perception, decreased as age increased, as well as global processing, to the benefit of integrated responses. This was observed as well in the naming as in the drawing task. However, there was a clear protracted period of local processing dominance in blind children. The protracted dominance of local processing in the development of blind children is certainly due to the sequential nature of the exploratory manual movements that are used by blind people to process shapes and prevent fast access to the global shape. Access to the global shape of unknown patterns requires highly developed mental capabilities for the coordination and integration of information and these capabilities need time to develop. At the age of about 11-12 years, the frequencies of global and local responses were quite similar (thus proved that EB children can attend to both local and global information) before decreasing in both tasks as the number of integrated responses increased in children at older ages. The integrated responses became the predominant response category at 11-12 years of age in both tasks, thus demonstrating that the difficulty in producing integrated responses was not due to specific graphic difficulties experienced by EB children. Although there were very few non-integrated responses in which the local and global components were present but juxtaposed, it is interesting to note that these occurred primarily at 9-10 years of age, that is

just before the integrated responses became more frequent than the local responses, and they disappeared at 13-15 years of age.

By contrast, the study with children with mental retardation did not provide results as clear as those with blind children with respect to development. Global processing dominance characterized these children with intellectual impairment whatever the age, the task, and the type of pattern (even the local bias-induced pattern elicited on average more global responses). This result fits with other findings, showing that children with mental retardation performed better in drawing the global shape than the local elements (Bellugi et al, 1990; Bellugi et al., 2000, Porter & Coltheart, 2006). Only one age effect was significant in the naming task: when children were exposed to the global-bias induced pattern, the integrated responses were more frequent in older children than in the younger ones. Although this age effect goes in the “good” direction (increase of integrated responses as age increases), it seems too isolated to be meaningful. One can argue that this result could be expected since the psychological development of children with mental retardation is more based on their mental age than on their chronological age. Indeed, we found more significant IQ effects in our study. The non-integrated responses (naming task) and the syncretic responses (drawing task) were less frequent in the higher IQ-group than in the lower IQ-group. Inversely, the production of total-integrated responses in the naming-task and of integrated responses in the drawing task was larger in the higher IQ-group than in the lower IQ-group. These results are coherent with findings concerning the involvement of cognitive mechanisms in the perceptual analysis (Poirel et al, 2008; Singh & O’Boyle, 2004).

However, these results tended to indicate that between 6-10 and 13-14 years of age, there is almost no development of perceptual analysis in these children with mental handicap. In one way, we could say that this demonstrates that children with mental retardation do not differ from typically developing individuals: they display a large global preference effect. This is what Dulaney, Marks and Devine (1994) concluded in their own study. However, the absence of significant evolution in the range of ages we studied continues to borrow us³.

³ We decided to run other analyses that were lacking in Chapter 4, testing for age effects inside each IQ group, despite that the distribution of the participants across ages was not regular. The higher IQ group included 7 children aged 6-10 years, 8 aged 11-12 years and 11 aged 13-14 years in the naming task, 7/7/9 in the drawing task. The lower IQ group included 20/7/10 children in the naming task, 19/6/9 in the drawing task. No age effects emerged in the low IQ group, whether the production of local, global and integrated responses were considered in the naming or drawing task (all $p_s > .50$). The results were a little bit more positive with the higher IQ group, but only at a descriptive level. The global responses decreased between 11-12 and 13-14 years of age and the integrated responses increased in the same period, in the naming and drawing tasks, but the differences failed to reach significance ($p_s > .20$). It is nevertheless encouraging, because the low number of participants per age group may be the reason why statistical significance was not reached.

The literature is not clear about the precise reason why people with mental retardation display this large global dominance effect. What seems clear is that the way visual information is processed in people with mental retardation is affected as compared to normally developing people, and also as compared to individuals with William Syndrome. Indeed, Bellugi et al.

(1999) reported that the functioning of both the ventral and dorsal visual systems is affected in adults with Down Syndrome.

Let's see now to what extent these trends in local-global processing could be affected by different contextual factors.

B. Contextual effects on local and global processing

Our studies demonstrated that local and global processing in children were sensitive to contextual effects, as also revealed in the literature (Prather & Bacon, 1986; Kinchla & Wolfe, 1979; Grice, Canham, & Boroughs, 1983; Pomerantz, 1983; Kimchi, 1988; Sanocki, 1993; Weber et al., 2000; Ninose & Gyoba, 2003). We tested two types of contextual effects: effects related to pattern properties (consistency, complexity, meaningfulness, duration) and effects related to gender.

Effects of different pattern properties

We investigated the effect of *consistency* of the hierarchical patterns in the two first experiments. The use of consistent and inconsistent stimuli had its roots in Navon's experiment (1977) with compound letter stimuli, followed by other studies using other forms of hierarchical patterns as geometrical or numerical patterns (Kimchi, 1992; Han & Xiao, 1999; Tanaka, Onoe, Tsukada & Fujita, 2001; Mondloch et al., 2003; Kimchi et al., 2005; Vinter et al., 2010). The pattern is defined as consistent when the global and local levels are matched and the pattern is considered as inconsistent when the global and local levels do not match. The aim of introducing consistent and inconsistent stimuli is to reveal *interference effects* between global and local processing. Global interference refers to the reaction time delay for local identification caused by the inconsistency at the global level. Local interference refers to the reaction time delay for global identification caused by the inconsistency at the local level. Previous studies suggested that these interferences are modulated, in part, by interhemispheric transfer (Robertson et al. 1993; Weissman & Banich 1999; Christman, 2001). These interference effects were worth investigating in children, in particular in young children who still have immature interhemispheric communication (Moses et al., 2002). Consistent and inconsistent haptic hierarchical patterns were also introduced to the early blind children with the same objective as in typical developing children.

In relation to the similarity-judgment task, our study found that the consistent stimuli elicited more global responses at young ages in typically developing children. Typically developing children produced more integrated responses in face of consistent than inconsistent patterns in a drawing task. These two effects are in line with the literature and suggest that pattern consistency reinforces global processing dominance and facilitated the integration with local processing. Coherently, the inconsistent patterns elicited an increase of inaccurate integrated drawings. If we assume that these patterns required more effortful processing, interference effects between local and global processing could be enhanced by these patterns, leading to less accurate reproduction of each level. More interestingly, inconsistent patterns elicited erroneous global responses in the similarity judgment task at 3 years of age, this result evidencing an apparently reverse interference effect with regard to the one reported in adults. Indeed, adults were shown to be subject to interference effects revealing diffusion from the global (dominant level) to the local level in the face of inconsistent patterns (Kimchi, 1988; Martin, 1979; Navon, 1977), while in our results, children's errors at 3 years of age revealed diffusion from the local (dominant level) to the global level. In our view, the opposition between the adults' results and the young children's results (global to local versus local to global interference) is only apparent because in the two cases, there is interference from the dominant to the non dominant level of analysis. The errors demonstrated by older children in the drawing task in face of inconsistent patterns (erroneous local responses) confirmed this analysis. Indeed, insofar as erroneous local responses to inconsistent targets revealed global to local diffusion, this effect emerged only on average across ages, congruent with the fact that on average, global processing dominated over local processing.

Consistency appears to have some effect also in haptic perception of hierarchical patterns. Consistent patterns induced more global responses in a naming task from early blind children, while more local responses were reported in case of inconsistent patterns. We have suggested that these findings may illustrate the use of a hypothesis testing strategy as described by Alexander, Johnson and Schreiber (2002) in their study of haptic exploration in children aged 4-9 years. Perhaps, EB children in our study tended to make the assumption that the pattern was unique when they perceived that the local elements had the same shape as the global configuration. In contrast, when there was a mismatch between the local shapes and the global configuration, the assumption was in favor of the dominant local information. If this account is correct, it would suggest that the way pattern consistency is manipulated differs greatly between haptic and visual exploration. It is unlikely that interference effects would occur during haptic exploration, as they do in the visual mode, because of the extended time course of global information processing in the haptic mode.

The second pattern property that was investigated in this thesis was related to the potential effect of pattern *complexity* with regard to global-local processing. We must recognize that we did not have a lot of expectations about the effect of this factor, due to the lack of corresponding studies in the literature. Our intuition was that the more complex the pattern was, the stronger global processing should be. Our results confirmed partially this intuition. In the similarity judgment task, more global responses were indeed provided in face of complex patterns but only by the younger children aged below 8 years. The reverse result emerged in the older children, with more global responses in face of simple patterns. The results from the drawing task pointed also to an opposition between younger and older children. More part-correct responses were obtained in face of simple patterns at younger ages, while in older children, the complex patterns did elicit better part-correct analysis. Young children produced also more partial responses in face of complex than simple patterns. Taking together, these results may suggest that complexity drew attention to the parts in the older children, enhancing a correct part analysis and diminishing slightly global dominance. In younger children, complexity acted negatively on part analysis, thus enhancing global dominance.

The third pattern property investigated in our experiments concerned the *meaningfulness* of the shapes located at the global or local level in hierarchical patterns. Previous studies that have introduced objects in the building of hierarchical patterns, suggested that objects should arouse automatic identification. Automatic identification at the global or local level should influence global or local precedence respectively (Poirel et al., 2006, 2008). These authors proposed that introducing objects at global or local level should not only challenged the global precedence effect in a way that the global level should not always be processed before the local one (depending on which level the meaningful objects were located), but they also showed that local interference existed. Their results confirmed that the presence of an object (familiar pattern) triggered an automatic identification process that facilitated performance when it occurred at the target level, and interfered with performance when it occurred at the irrelevant level. Our aims were similar to those suggested by Poirel et al. (2006, 2008) in using meaningful (familiar object) and non-meaningful (non-object) stimuli at both the global and/or local level in a naming task and a drawing task administered to children with mental retardation. Previous studies indicated that children with mental retardation showed global bias in attention with difficulties in processing at the local level (Birhle et al., 1989; Porter & Coltheart, 2006). By introducing meaningful objects at the local level, we expected to enhance local analysis in children with mental retardation.

Our results showed that global processing dominated the children's responses both in the naming and drawing tasks. This was not particularly reinforced by the presence of meaningful objects at the global level (global bias-induced patterns), since the global

responses were also highly induced by the neutral pattern (non-object figures at both levels). More interestingly, as expected, in the naming task, the local responses were more elicited by the local bias-induced pattern (meaningful objects at the local level) and also by the competition-induced pattern (meaningful objects both at the global and local level), in comparison to the neutral pattern. Although the frequencies of the local responses were low as compared to the global responses, these findings evidenced the emergence of a local preference when meaningful objects were present at the local level. The results obtained in the drawing task were less clear in this respect. The competition-induced pattern elicited more local responses than the local bias-induced pattern, but this was observed only in one age group. Whatsoever, it testifies for the fact that local interference can exist in children with mental retardation. Otherwise, the global responses were more frequent for the global bias-induced pattern than for the neutral pattern, thus showing that global processing could still be reinforced in children with mental retardation.

Finally, the fourth pattern property that was tested in our experiments concerned the *duration* of exposure of the hierarchical patterns. Previous studies showed that interference between the global and local levels was affected by exposure duration (Pomerantz, 1983; Paquet & Merickle, 1984, 1988; Motttron & Belleville, 1993; Plaisted et al. 1999; Kimchi, 2005). More precisely, these authors presented compound letters at various durations of exposure and reported that a unidirectional global to local interference was found at the shortest exposure duration. Longer exposure durations were found to elicit more local responses since prolonged viewing reduces the efficiency of global processing (Ninose & Gyoba, 2003) and short durations on the other hand, were found to facilitate the global precedence and global interference effects (Allison & Fernandes, 2006; Wang, Motttron, Peng, Berthiaume, & Dawson, 2007; Hibi, Takeda, & Yagi, 2002). Some authors suggested that duration related to attentional processes in the analysis of hierarchical patterns. Inhibitory mechanisms (suppression of distraction derived from the analysis of unattended objects) to local elements would be present when subjects directed their attention to the global level with the short durations, whereas at the long exposure durations, inhibitory mechanisms to local elements would not be present, thus leading to a more local advantage (Robertson, 1996; Hibi et al., 2002).

In our thesis, manipulations of durations of exposure were introduced in Experiment 1 to Experiment 4 with the typically developing children. A long duration (3 seconds) and short duration (300 msec) was applied. Our study confirmed that when children were presented with patterns at long and short durations in the similarity judgment task, their choices for local responses was more frequent with long than with short durations. This result was mainly found in children aged 3 to 6-years, that is, until global processing preference was clearly established. It is interesting to note that the higher production of local responses under

long stimulus durations in comparison with short durations clearly argues against the oculomotor hypothesis evoked by some authors to account for the local dominance at early ages (Kowler & Martins, 1982; Poirel et al., 2008). These effects of duration were much less clear in the experiment involving complex hierarchical patterns.

Manipulation of duration in the drawing task with consistent and inconsistent stimuli showed only a marginally significant impact. Short durations tended to elicit more local responses, mainly in the 3-year-olds. This effect was in opposition with the one obtained in the perceptual experiment, but it was confirmed by our third experiment concerning the simple and complex stimuli, where short durations tended to elicit more local responses in the younger children (4-year-olds). This opposition points to the difference between the similarity judgment task and the drawing task. Only the drawing task requires the formation of a representation of the stimulus. In the similarity task, different possible choices are provided. Thus, duration may have an effect on the formation of a complete representation of the perceived pattern particularly in young children. This interpretation is coherent with the results obtained in the experiment concerned with the complex hierarchical patterns. Indeed, they showed that a correct part-whole analysis was better achieved when the patterns were presented at long durations.

Gender effect

Gender was the last variable that we included in the study because the literature seems to be quite contradictory with regard to the impact of sex on local/global processing: In some studies, boys have been reported to make significantly more global perceptual judgments than girls (Cahill, 2003; Kramer et al., 1996). This is consistent with developmental models that suggest an early left-hemisphere advantage for girls and a right-hemisphere advantage for boys (Denckla & Rudel, 1974; Kirk, 1992; Coluccia et al., 2007). However, Dukette and Stiles (1996) mentioned exactly the reverse result in 4- to 6-year-olds and in adults in a force-choice matching task, with female participants making more global level matches than male participants. For their own, Kimchi, Amishav and Sulitzeanu-Kenan (2009) did not report any gender differences in global-local processing. Gender differences were therefore worth investigating.

Unfortunately, most of our results showed that the effects of gender were not significant. Only in our last experiment concerning the haptic global-local processing with early blind children, significant effects of gender were reported. Some authors have investigated gender effects in haptic perception (Vecchi, 2001; Zuidhoek et al., 2007). Vecchi (2001) showed that blind females tended to develop less efficient strategies than blind males when active processing was required in a complex task. This could suggest that blind females

might process information differently from males when confronted with inconsistent hierarchical patterns.

In both the naming and drawing tasks, the girls produced local responses more frequently than the boys. This result provides support for the findings reported by Steri et al. (1996) which suggest that girls process haptic information analytically and discriminate details, especially when employing the right hand. It is also consistent with developmental models that suggest that the left hemisphere is favored early in girls (Collucia et al., 2007), as the left hemisphere has been found more efficient than the right one for local information processing (e.g., Lamb et al., 1989). Furthermore, in the naming task, the boys produced integrated responses more frequently than the girls. Vecchi (2001) found that blind males developed more efficient strategies than females when active processing was required in a complex task. The gender differences we observed might primarily be due to similar differences in information processing strategies, with the boys deploying more efficient strategies for the coordination of local and global information in response to the more complex patterns (the inconsistent patterns). However, they may also be due to more basic differences in haptic perception, given that Zuidhoek et al. (2007) found that males performed better than females in a variety of tasks assessing the haptic perception of orientation. It is worth pointing out that this issue on gender differences remains quite confused. Kimchi, Amishav, and Sulitzeanu-Kenan (2009) did not report any gender differences in global-local processing, but their study concerned adults and included visual tasks. Furthermore, the literature shows that gender differences exhibited in visual tasks (for instance, in the rod-and-frame task or in the water-level task, Voyer & Bryden, 1993, Robert & Ohlmann, 1994) are eliminated in tactile versions of these tasks (e.g., Walker, 1972; Robert, Pelletier, St Onge, & Berhiauume, 1994). Defining more precisely what may underlie the gender differences observed in our experiment appears therefore delicate, and further research on this topic is needed for clarification. The only gender difference that is coherent with the overall literature was obtained in the drawing task, where the boys produced more scribbled drawings than the girls. Many studies have revealed that girls achieve better performances than boys in tasks requiring fine motor abilities (e.g., Fairweather, 1976; Kraft & Nickel, 1995).

Conclusion

The effects of age, pattern properties, duration and gender showed that there were quite clear evidences that there are different characteristics that marked the milestone of children's development of global-local processing. Concerning age, we can conclude that until 3 years of age, typical developing children showed local preference. The move to global

preference emerged at 4 years of age, and then the two levels of processing begin to integrate at 5 years of age, followed by further refinement until 9 years of age, and probably still later. Before 5 years of age, children can actually attend to both levels of perceptual analysis, but it seems that these processes operate independently, as could be suspected from the immature interhemispheric communication (Liegeois et al., 2000). This is also highly congruent with predictions that can be drawn from some of the neo-Piagetian theories that claim that 3-year-olds can focus only a single dimension of a task, whereas 5-year-olds can focus on two (Case & Okamoto, 1996; Halford, 1993; Pascual-Leone & Johnson, 2005), and also related to the difficulties encountered by young children in the understanding of parts-whole relationships, as shown in drawing studies (Picard & Vinter, 2007; Tada & Stiles, 1996; Vinter, 1999; Vinter & Marot, 2007) or in cognitive tasks (e.g., Inhelder & Piaget, 1964). This developmental sequence of local-global processing was similar between the typical developing children and early blind children, although there is a protracted period of local processing dominance in EB children. According to our study, the local processing dominance in EB children continued until about 10 years of age and, at the age of about 11-12 years, the frequencies of global responses increased and were quite similar to the frequencies of local responses (thus proving that EB children can attend to both local and global information). Both of these responses decreased as the number of integrated responses increased in children at older ages, so that the integrated responses became the predominant response category and still continued to increase in children at older ages.

These age changes were only suitable to describe the development in typical developing children and early blind children, but not in children with mental retardation. Indeed, in these children, no age effect emerged, only IQ effects, and these last effects were not as strong as age effects in typically developing children. There was a clear global processing dominance in these children across ages and also across IQs, though the integrated responses developed as a function of IQ in the drawing task. However, interference effects existed in these children, as shown by the increase of local processing when meaningful objects were located at the local level. This means that these children are able to attend to both processes, but local processing needs to be enhanced by external cues. Dulaney et al. (1994) also showed that local processing can be enhanced in persons with mental handicap by appropriate training. Of course, we can wonder to what extent the heterogeneity of our population of children with mental retardation did not prevent to obtain clearer developmental trends in these children. Replications with better control of the etiology of the intellectual impairment seem necessary. The age range of our sample of children with mental retardation was also not sufficient, as it did not include young children, who could more inclined to process at a local level if development of perceptual analysis bears some similarity between typically developing children and children with mental retardation. We can also wonder to

what extent potential cultural differences did not interfere in our studies involving only Indonesian participants (with mental retardation, with visual impairments). Indeed, some cross-cultural studies reported that east Asian individuals showed a strong global advantage relative to Caucasian persons (McKone et al., 2010). It thus could be that the global advantage observed in our sample of children with mental retardation may be somewhat greater than could be observed in western participants. All these arguments contribute to suggest that further research is needed on this topic with children with mental retardation.

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Abstract : The thesis investigated the development of children's global/local processing hierarchical patterns introduced by Navon (1977). The objectives were to understand more comprehensively the developmental characteristics of children's perception through their global and local processing of hierarchical patterns, by considering the effects of age, stimuli properties, duration of exposure to the stimuli and gender in a perceptual task and a drawing task. These effects were tested in 3 different populations: typically developing children, children with mental retardation and early blind children. The results revealed that typically developing children attended to both the local and global level of processing but these modes of spatial information processing operated independently. In a first step, children before 4 years of age showed dominance of local processing and then a more global processing developed at 4 years of age, and at 5 years of age integrated responses began to emerge. Early blind children showed similar developmental characteristics, although there was a protracted period of local processing dominance. Indeed, these children mainly produced local responses at ages of between 6 and 10 years, and then developed more global responses at 11-12 years and continued to integrate the two levels of analysis at later ages. On the other hand, global dominance was shown in children with mental retardation and their development was affected more by mental age than by chronological age. Moreover, their responses were shown to be sensitive to the fact that meaningful object could be located at the local level, enhancing local processing in this case. These results need further confirmations as the studies of global/local processing in atypical children are not numerous. In particular, the effect of duration of exposure to the stimuli should be further analyzed, because this factor did not seem to have a great effect in our experiments while it seemed more powerful in other studies carried out with adults. Replication of the study with children with mental retardation appears also important to plan for future work, because we can have some doubt relatively the absence of modification through ages of the way these children perceive hierarchical patterns. Finally, defining more precisely what may underlie the gender differences seems also worth to explore since gender did not show a major effect in our results.

Keywords : global processing, local processing, hierarchical patterns, typically developing children, children with mental retardation, early blind children, drawing task, naming task, similarity-judgment task.