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Children's Line Drawings and Object Representation Strategies: Categorization of Children's Mental Representation Strategies According to the Existing Theories for Object Recognition by Studying Line Drawings

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Abstract

Mental representation of objects deals with understanding the imagery information of concepts and provides clues for design and implementation of computational object recognition strategies. In this study, I postulate that studying of children's drawings can provide useful information about mental representation of objects in preliminary stage of developmental learning. To this aim, I have designed an experiment in which I asked children of ages 3-4 to draw objects from known categories. Children were also allowed to have a brief view to a prototypical picture of objects for a short period of time. Based on my observation derived from children's drawings, I classified children's strategies for object representation into three main categories: part-concept, familiar-concept and shape-concept. Results from this experiment suggest that there is a strong link between early object representation and theories of object recognition.

Keywords: *Object recognition; object representation; children's drawings*

1. Introduction

A number of studies about different aspects of cognitive understanding have been conducted on children. These studies span from different cognitive problems such as superordiante/subordinate categorization (*e.g.,* [1]), living/ non-living concepts (*e.g.,* [2]), and perceptual/conceptual understanding. One of the common methods used in experiments with children from 13-30 months is the sequential touching procedure in which a tray of objects is offered to children [3]. Touching behavior of children in selecting objects is then used as a measurement of conceptual understanding in children. The process of concept formation and category development in children of different ages has already been a common interest of many researchers (*e.g.,*[4]). In fact, substantial research has been devoted to explore how objects are represented in mind and how the experience with concepts are capsulized into prototypical information. In this direction, many different theories have been developed that discuss how the objects, concepts, and categories are stored in mind. A readable approach to deal with this question is studying the behavior of children which potentially carry rich information about early learning process of human brain. In essence, the way children recall objects from memory and draw them can be a mirror of their mental representation [5]. Moreover, studying the categorical representation used by children can help us to understand the mental development in early ages [6]. In this paper, I intend to derive clues about concept abstraction and object representation in early stage of life and categorize children's drawings of objects by studying the drawings of children of age three to four. Children's drawings have received attention from psychologist esp. in studying of concept development over age (*e.g.,* [7]). For example, Cherney *et. al.,* studied working memory of children by asking children to draw their family and their schools [5]. In order to

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explore visual object representation in children, I concentrate on children's line drawings. Drawing is a visual language that reveals information about how people think, and hence children's drawing might illustrate how children explore and understand their environment [8]. Although the drawings of very young children are assumed to be scribbles, older children's drawing can unravel what they know about the visual appearance of their known concepts [5] and can give researcher many clues about children's mental development. In fact, children's drawing is an indirect way of collecting data without interviewing with them [9] and it can provide information about their representational world. Children's drawings have been considered as a window to view children's intelligence [10], as a tool to discover their cognitive strategies [11], and categorization. Drawings of children also have been used as a diagnostic aid for discovering deviant and emotional problems[12].

There are many parameters that might influence children's drawing, like society, schooling [5], and culture [13]. In the present study I have focused on children from same nationality and culture. It may be argued that children's drawings are not a reliable source of information and children require a special training in order to develop their motor abilities and learn how to draw basic shapes. However, researchers suggest that drawing skills are not a necessary requirement and does not affect the way that mental representation are visualized on paper (*e.g.,* [14]). In addition, Gallagher argues that children's drawing reflects their innate understanding and it is not much influenced by the environmental instruction [15]. In my experiment, I recruited preschoolers ages 3-4. In this range of age, the early visual understanding and category learning is mostly completed and so children are more conscious and confident about their understanding of objects and their names. Studies show that the basic understanding of the analogical space-object-symbol relation starts around age 3 [16]. I also examined whether there would be a difference between male and female children in object representation strategies. It has shown that gender motor skill differences can affect the drawings of male and female children [17]. In [5] it is reported that there is a gender difference in children drawings of family. Also, human figures drawn by girl and boy are compared in [18] and it is demonstrated that their responses are different.

2. Related Works

One of the common and classical hypotheses about object recognition is based on the assumption that it is a template matching process, *i.e.,* primate's brain store an abstract representation for each group of objects and the recognition process is based on similarity matching process (*e.g.,*[19]). Broadly speaking, there are two different theories for object recognition, namely local and global approaches. In global strategy, it is argued that it is the whole shape of objects that matters in object recognition, while in the local strategy, it is assumed that salient regions appeals attention and leads to object categorization. However, part based theory which is also known as recognition by components is based on the view that individual 3-dimensioanl components or geons can be put together to construct visual objects [20]). These theories are also known as view-invariant object recognition, which is based on the assumption that invariant features or parts can provide sufficient information for object recognition. In contrast, global approaches or shape based methods for object recognition are dependent upon the representation of whole shape or contour of objects. According to this class of theories, objects are perceived by their holistic shape and not by their individual parts [21] and hence, the general form of objects observed in a specific viewpoint plays an important role in identification and categorization of objects.

For decades, the development of visual object recognition in children have been an interesting line of research. Many experiments have examined on children to understand how they categorize objects. In [22] the developmental differences between young (4 to 6

year old) and older (8 to 10 year old) is studied and it has been found that while young children's drawings differ in size and shape, the change in older children's drawings is related to position and orientation. There are many open questions regarding to the categorization process in children. Many researchers have been addressing the question whether children begin by understanding broad categories and they realize the fine details as they grow (*e.g.,* [23]) or they first learn objects from specific classes and the recognition of more general and conceptual classes emerges later [24]. The ability of children to distinguish between artificial vs. natural objects is another question related to categorical capabilities in children (*e.g.,* [25, 26]). Yet another active area of research has been concerned with the representation of objects used by children. Bloomington et al. focused on viewing effects in object recognition and indicate that there are two viewing biases in children: planar views (*i.e.,* views of objects held perpendicular to the line of sight) and the bias for upright orientation [27]. In [28] it has shown that children categorize superordinate classes based on part differences. In two experiments conducted on 18-30 months old children, the effect of objects' parts and their spatial relation on novel and common objects are examined and it is reported that children use part-based approach for recognizing common objects and they only attend to the interrelation between parts when objects are seen for the first time [29]. On the other hand, in [23] it is shown that infants categorize objects based on their shapes and materials. Gallagher has also identified six main basic shape categories used by children in their drawings [15]. In accord with this, art made by young children has also been considered to follow Gestalt theory which mainly refers to global tendencies and the holistic visual perception [5]. It is also suggested that there is a tendency from shape-based recognition to more structural-based recognition as children grow (*e.g.,* [28]).

3. Method

The experiments are done on twenty seven children ages three from an Iranian kindergarten. They were assessed by asking to draw a sketch of an object. A prototypical image of each object was also shown on computer monitor and remained for about 30 seconds to assure that children are aware of what they are asked to draw. When the image is appeared on the screen, all children mention the name loudly and therefore it is made sure that they all know the object in question. Therefore, the image on the screen only helps children to retrieve the stored visual information about an object from their memory. Moreover, it is explained to them that they have not to copy the images but rather to draw what they know about the object. Hence, children are not biased with images they have observed and the visual information is merely provided as a way to trigger children's mind about the questioned concept. All through the experiment, an instructor checks on children one by one an in case a chilf could not draw anything, the instructor talks to her and asks her question such as "how does the object look like?", Or "what the object is used for?" Sample images from the stimuli set are shown in Figure 1. The stimuli set are selected in a way to contain both animate and inanimate objects but the images are selected in a way to be easily recognizable for children.

phone glasses shoe

Figure 1. Sample Images of Stimulus Set (Target Objects)

4. Results

I grouped mental representation strategies of children into three conceptual classes: shape-concept, part-concept, and familiar-concept. In shape-concept strategy, children tend to visualize objects by leveraging holistic shape information. Concretely, objects of this category are abstracted by using simple shapes such as circles, lines, and squares (Table 1). Examples of children's drawings of this group are displayed in Figure 2.

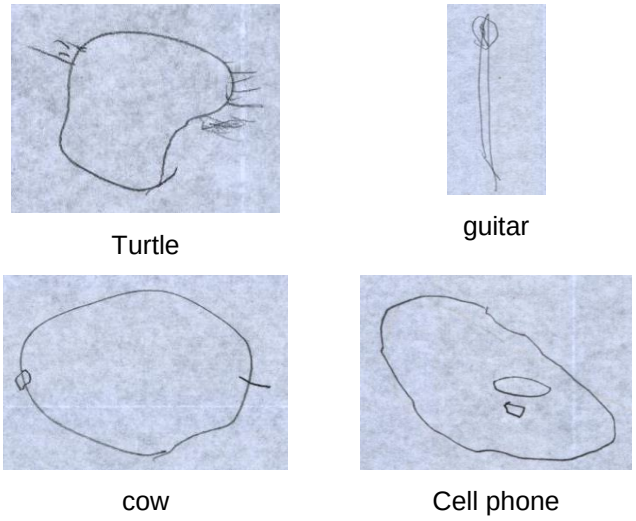

Figure 2. Samples of Pictures Drawn by Children Categorized as Part-based Concepts

Table 1. Basic Shapes Utilized in Children's Drawings

object	Basic representative shape
car	circle
Washing machine	Circle, lines, square
Turtle	Circle, lines
guitar	Lines, circles
cat	circle
chair	Square/rectangle
glasses	Lines, circles
tree	Lines, rectangle
glass	Line, circle

In contrast to shape-concept strategy, part-concept strategy concerns with component based representation. Drawings of this category are more tended towards specific part of an object which contains distinguishing descriptive information. Table 2 lists the name of the salient objects' parts from children's viewpoint in my experiment. In addition, Figure 3 shows examples of children's drawings following the part-concept category.

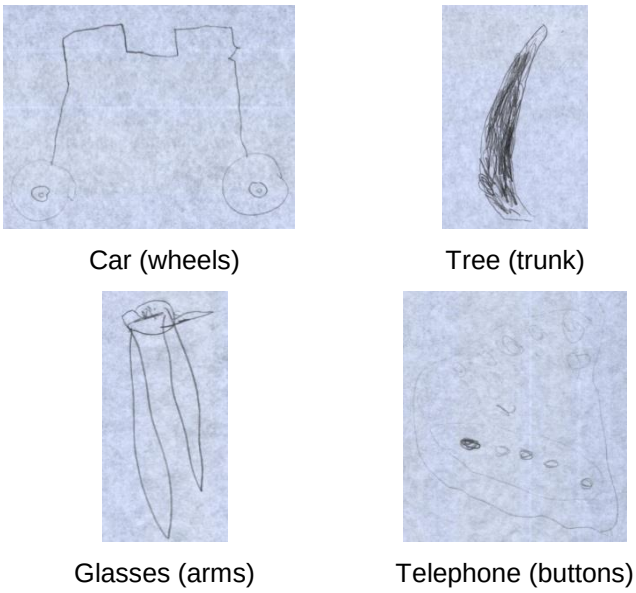

Figure 3. Samples of Pictures Drawn by Children Categorized as Part-Based Concepts

Table 2. Parts of Objects Utilized in Children's Drawings

Target objects	Representative parts
cow	Horn-legs
turtle	Head-legs-shell
car	wheels
tree	Trunk, leaves
bird	Head, legs, beak
glass	holder
phone	Buttons, keys
chair	legs
glasses	arms
shoe	laces

Finally, familiar-concept strategy is based on the observation that children tend to relate to unknown and esp. difficult objects by taking advantage of their information about known and familiar objects. For example, as seen in Figure 4, difficult animals are simplified by a familiar concept of human form. It can also be implied that this mapping might be resulted from children's books and films that humanize animals. Other

simplified images reflecting the familiar-concept strategy are presented in **Error! Reference source not found.**

The results of my experiment show that children apply familiar-concept group mostly to animate objects. For example, many of children drew human shape as a representation of animals and some used flower concepts to represent trees. However, shape-concept and part-concept strategies appeared to be more employed for difficult (*e.g.*, phone, cow) and less familiar (*e.g.*, guitar and washing machine) objects. It is noteworthy to mention that some exceptional three-aged children were able to draw objects with high details in a way that was very similar to the target objects which could be a sign of their quicker learning development compared to their peers.

Turtle (human) Cat (human)

Figure 4. Sample Pictures Categorized in Familiar-Concept Strategy

Table 3. Familiar Concepts Used by Children

Objects	Familiar concepts
Washing machine	house
Turtle, horse, cat	human
Tree	flower

5. Discussion

In this section, I provide a more accurate discussion about the obtained results. As mentioned in previous section, I divided children's strategy for object representations into three categories. It can be simply implied that these categories as explained in the previous section are strongly connected to existing theories about object representation. The first category which is called shape-concept strategy refers to a representation technique which is based upon information associated to the whole configuration of objects. Holistic object perception and representation is known as the most recognizable theory of mental representation which is consistent with Gestalt principal and has been applied in many object recognition tasks. In [30] shape based descriptors are utilized for classification of animal vs plant categories. The second group or part-concept group is marked with usage of specific components which can be served as diagnostic cues for identifying members of a category. Theories in favor of part-based visual object representation are mainly supported by Biederman's theory [20]. Finally, familiar-concept strategy points out to the familiar notions which are sometimes preferred by children as a simplified form of representation. This strategy may also include the imagery representations which are formed by frequently seen objects. Experimental studies have suggested that children overgeneralize name of objects to the more frequently seen categories [31]. Note that, sometimes children draw a head or face as a representation of animal concept. In such cases, the drawing is classified as a member of part-concept group if at least one particular feature of that animal could be noticed in the drawing; otherwise, it is decided to incorporate into familiar-concept strategy because it

is more likely to be inferred as a head of human. It is noteworthy to mention that through the experiment there is a direct communication with children, and in case an image does not appear to correlate with the target object, children are asked to explain what they have drawn and their drawings are labeled according to their description.

Error! Reference source not found. Table 4 provides numerical information about number of drawings in support of each strategy. In addition, two more columns are added which include information about two other groups of children: those who could draw object images very well, and those who just scribble and couldn't draw a meaningful picture. These groups are titled "complete figures" and "unidentified figures" respectively. All results are also shown in two parts based on their superordinate (artificial/natural) categories. Also, the number of participated children along with their gender is specified for each object. The last row of each group represents the accumulated number of participants corresponding to each concept strategy and the significant results (any differences above 3) are shown in bold. Histogram plots (Figure 5 and Figure 6) corresponding to the obtained results can be interpreted as follows: Shape-concept is the dominant concept and it is probably the easiest strategy that is used by both genders. This finding might support the idea that a whole representation of objects which is sometimes known as gist (*e.g.*, [32]) is learned and recognized before much specific details of objects. Furthermore, part-concept is fairly equally applied by both female and male children. Moreover, familiar-concept is mostly used by female children, which may suggest that girls more likely use their imagination to match new items with their previously known concepts than boys do. Also, my results suggest that male children tend to scribble much more than girls. However, the ability of drawing objects completely in good amount of details is seen much more among boys than girls. In addition, the results indicate that familiar-concept is majorly used for representing natural objects. In contrast, shape-concepts are more applied for displaying artificial objects.

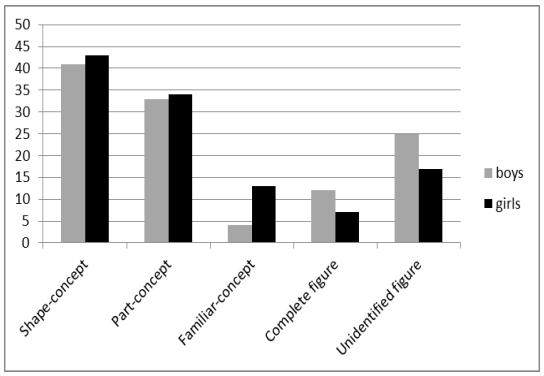

Figure 5. Categorization of Children's Drawings by Gender

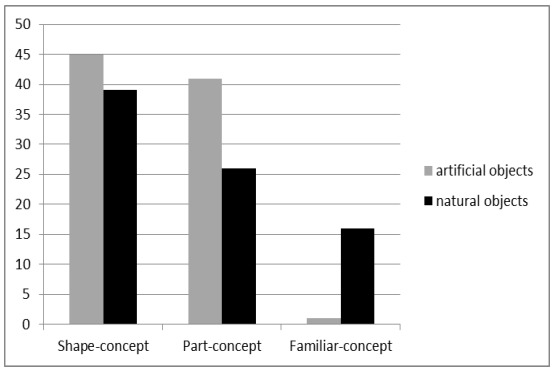

Figure 6. Categorization of Children's Drawings by Superordinate Level of Objects

Table 4. Children's Strategies used in Representing Objects

Target objects	**Shape-concept**		**Part-concept**		**Familiar-concept**		**Complete figures**		**Unidentified figures**		**Participants**	
Drawn by a:	**Girl**	**Boy**	**Girl**	**Boy**	**Girl**	**Boy**	**Girl**	**Boy**	**Girl**	**Boy**	**Girl**	**Boy**
Artificial Objects												
Washing machine	5	5	1	0	1	0	2	1	1	1	10	8
Chair	3	1	4	3	0	0	0	0	2	4	9	8
mug	1	2	1	1	0	0	0	1	2	2	4	6
Car	3	2	3	4	0	0	0	0	1	1	7	7
Guitar	4	4	1	1	0	0	0	2	0	1	5	7
cell phone	1	2	3	4	0	0	1	0	0	1	5	7
telephone	3	1	3	2	0	0	0	0	1	1	7	4
glasses	2	0	2	3	0	0	1	2	2	4	7	9
Shoe	3	3	2	3	0	0	0	0	1	0	6	6
Subtotal	**25**	**20**	20	21	1	0	4	6	**10**	**15**		
Natural Objects												
Bird	4	1	3	1	1	0	0	1	2	1	10	4
Turtle	3	4	1	0	1	0	0	1	1	2	6	8
Cow	1	3	3	1	0	2	0	1	1	2	6	9
Horse	2	2	1	2	3	1	1	1	0	2	7	8
Cat	2	4	1	2	2	1	1	1	0	1	7	8
Tree	2	4	3	2	1	0	1	1	2	2	7	9
Rooster	4	3	2	4	4	0	0	0	1	0	11	7
Subtotal	**18**	**21**	14	12	**12**	**4**	**3**	**6**	**7**	**10**		
Total	43	41	34	33	**13**	**4**	**7**	**12**	**17**	**25**		

6. Conclusion

In the present study I attempted to obtain clues about early object representation in children by making a psychophysical experiment on children. I decided to work with children based on the assumption that in the early years of life, learning and recognition process is at its highest level of activity and the object representation strategies are at a developmental stage. Hence, object representation mechanism has not yet completed and it follows simple rules which might be easier to study and simulate.

In my experiment, children ages three were asked to draw images of known object categories. Images of prototypical object categories are exposed to children for 30 seconds. The short viewing interval prevents children from copying the displayed image on the screen. As another possibility, I could only tell children to draw an object by mentioning its name, but I found that children respond more efficiently to the image of objects than to their names.

Note that I don't claim that children's drawing could reveal exact information about children's mental representation, but I conjecture that there is a correlation between children's drawing and their stored mental representation. In the results of current experiment I could recognize three main strategies that interestingly correlate with the existing object representation theories. I called these strategies shape-concept, part-concept and familiar-concept. In fact, while children's drawing is an insufficient source of information for understanding children's visual object representation, it can reveal interesting and fruitful information for conceiving or justifying some theories which has already been applied in the field of machine vision, cognitive science and psychology. I also observed that children don't apply a single strategy or policy for drawing different objects, which implies that children's drawings are not dependent on their motor abilities and they deliberately choose an appropriate strategy for different categories of objects.

There could be many reasons why some children are capable of producing more accurate pictures and drawing with fine details, such as innate drawing skills and having more practice or better coaching. Even children's characteristic like being more patient or more careful might play an effective role in children's drawings. However, the scope of this paper is not focused on the external/internal causes of children's drawing abilities. Rather, this paper investigates object representation strategies and the clues from children's drawings. My hypothesis is that children's drawing could be a way of understanding their mental object representation. However, other possible approaches might be asking them to describe objects verbally or recording FMRI signals while they are drawing an object. My experiments with children have shown that children's behavior in recalling object visual information is similar to existing theories in machine vision. In addition, my results reflected cognitive and behavioral differences among female and male children in representing objects.

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