Taxonomic relations and cognitive economy in conceptual organization

Anna M. Borghi (borghi@psibo.unibo.it)
Department of Psychology, 5 Viale Berti Pichat
Bologna, 40127 ITALY

Nicoletta Caramelli (ncaramelli@psibo.unibo.it)
Department of Psychology, 5 Viale Berti Pichat
Bologna, 40127 ITALY

Abstract

This study, performed on children aged 5, 8, and 10, and on adults, deals with conceptual knowledge organization using a word association task. Participants were presented with concept nouns at superordinate, basic, and subordinate level. Their productions were coded according to 4 kinds of relations: taxonomic, thematic, attributive, and evaluative relations. The following results were found at all the considered ages: a. not only lower but also superordinate level concepts elicit attributive relations; b. the production of thematic relations outnumbers that of taxonomic relations thus showing that there is no thematic to taxonomic shift. These results suggest a revision of the criteria on which cognitive economy rests in knowledge organization that will probably lead to a more complex view of the cognitive economy principle.

Introduction

Many models of conceptual organization, from the classical theory and its revised version, the binary theory, to the prototype and some connectionist models, but not the exemplar models, rest on the assumption that the cognitive economy principle underlies both the storing and the retrieval of conceptual information. Accordingly, concepts are defined by the properties and the attributes that establish their identity as well as by their relationships. It is the hierarchical organization of taxonomic relations binding them together that allows people to infer the shared properties and attributes which make the conceptual network coherent.

In this perspective, cognitive development is a progression towards the attainment of this taxonomically and hierarchically organized knowledge structure. During development children undergo a thematic - to - taxonomic shift that is responsible for their mastering their dealings with the environment. This is possible thanks to a well structured knowledge organization that rests on the hierarchical array of taxonomic relations. Thus, cognitive development involves the transition from a contextual or thematic knowledge, based on the acquisition of recurrent properties of objects and events directly experienced, to a more abstract knowledge based on the taxonomic relations responsible for the way objects and events are grouped into categories (Lucariello & Nelson, 1985; Lucariello, Kyratzis & Nelson, 1992).

It is reasonable to argue, however, that also information that is not necessarily inferred from the hierarchical levels of concept plays a relevant role in conceptual organization. It has been claimed that conceptual knowledge is situated and contextually set up (Tschacher & Scheier, 1999). In everyday life, at different times, people perceive different objects in the same spatial context. On the other hand, the same object can be perceived in different spatial contexts (Barsalou, 1993, 1999; Barsalou & Hale, 1993; Barsalou & Prinz, 1997).

In cognitive development these arguments lead to the questioning of the traditional cognitive economy principle based on the hierarchical organization of conceptual knowledge. Some authors have pointed out that the kind of task given to children biases their preference for thematic or taxonomic relations (Waxman & Kosowsky, 1990; Waxman & Namy, 1997) and that thematic relations still play a role in both older children's and adults' conceptual organization (Markman, 1989; Sell, 1992). Therefore there should be no reason to suppose that children undergo a thematic - to - taxonomic shift, i.e. that, with age, the taxonomic organization of conceptual knowledge replaces thematic knowledge (Osborne & Calhoun, 1998).

Moreover, other approaches assume that even abstract information is grounded in perception and action (Barsalou, 1999; Glenberg, 1997; Mandler, 1992; 1997; Smith, 1995; Smith & Heise, 1992). However, these views based on the role of perception and action in shaping conceptual knowledge deal with difficulty with superordinate level concepts, i.e. concepts, as 'animal', that do not refer to a particular, concrete referent.

This study is aimed at shedding some light on two points: a. does thematic knowledge concur with the taxonomic organization of concepts in shaping knowledge in children as well in adults, instead of

loosing its relevance? b. Can superordinate level concepts, not referring to concrete objects, convey perceptual information?

In order to answer these questions, the following hypotheses can be advanced:

1. Hierarchical Levels: if perceptual and action views of categorization hold, superordinate level concepts, not referring to concrete objects, should convey not only abstract but also perceptually and action grounded information. As their activation should involve the activation of their exemplars, they are also expected to elicit attributive relations (Callanan, Repp, McCarthy, & Latzke, 1994; Markman, 1985). Moreover, the relations elicited by basic and subordinate level concepts should be more similar to each other than those elicited by superordinate level concepts as both of them refer to concrete objects. Therefore their activation should elicit mainly attributive and thematic relations.

2. Conceptual Relations: assuming the perceptual and action views of categorization, the perceptually and contextually grounded thematic and attributive relations should characterize not only children's but also adults' conceptual organization. Therefore no thematic - to - taxonomic shift should occur.

These hypotheses were tested on children aged 5, 8, 10 in experiment 1, and on adults in experiment 2. Participants were given a word association task to be performed on concepts at different hierarchical levels, i.e. superordinate (e.g. animal), basic (e.g. dog), and subordinate (e.g. hunting dog) level. The conceptual relations produced by participants were classified as taxonomic, thematic, attributive, and evaluative (Chaffin, 1992; 1997).

Experiment 1

Method

Participants One-hundred and twenty middle class children, 40 aged 5, 40 aged 8 and 40 aged 10, living in Bologna and the surrounding area took part in the study.

Materials To maintain children's attention, only 9 concept-nouns were selected, 3 superordinate (e.g. furniture), 3 basic (e.g. chair), and 3 subordinate level concepts (e.g. high chair). The basic level was defined by the common shape criterion according to which basic level concepts whose members share a common shape are the most inclusive ones (Lassaline, Wisniewski, & Medin, 1992). The superordinate and the subordinate levels were defined respectively as more general and inclusive and more specific than the basic level. All the selected concepts were countable nouns.

Procedure The children were interviewed, one at a time, in their kindergarten or school. They were presented with a booklet. On each page there was a circle and at its center there was a concept-noun. They were asked to say and then to write on the circle from a minimum of 5 to a maximum of 10 associations to each concept-noun. The circle was supposed to prevent children from producing chain-like associations. The free association task, already used with success also with very young children (Nelson, 1986; Sell, 1992), was introduced to the children as if it were a game. At the end of the task, to better assess the intended meaning of the produced associations, the experimenter asked the children why they had said or written what they had said or written for each produced association and tape-recorded their answers.

Coding The data were transcribed and coded by two independent judges (2% cases of disagreement solved after brief discussion), according to 4 different kinds of relations (A) Taxonomic Relations: including superordinate, subordinate, and co-ordinate relations: e.g. 'bird-animal', 'bird-parrot', 'sparrow-parrot'. The production of taxonomic relations does not imply that children master class inclusion (Greene, 1994); (B) Thematic Relations: including spatial (physician-hospital), temporal (bird-spring), action (agent, object, and action) (bird-flies), function (chair-to sit on), and event relation when the child reported a whole story; (C) Attributive Relations: including partonomic (chair-leg), property (chair-brown), and matter relation (chair-wood); (D) Evaluative Relations: including meta-linguistic evaluations (oculist-I don't like him/her) as well as stereotyped associations (bird-airplane).

The relations that could not be included in the previous categories, 2% of the relations produced, were not analyzed.

Data analysis and results

To test the hypothesis 1, the percentage of the 4 kinds of the produced relations was computed for each age level and for each hierarchical level (see Table 1, 2, and 3). Three Correspondence Analyses were performed in order to verify whether, at each age level, the distribution of the frequencies of the 4 groups of relations varied across the hierarchical levels. In this analysis, based on the chi square test, the frequencies of the produced relations, from which a broad data matrix is derived, allow the identification of the weight of the different coded dimensions and their graphical representation. On the graph, the geometrical proximity of the points shows the degree of their association and the similarity of their distribution (Hair, Anderson, Tatham & Black, 1992; Greenacre & Blasius, 1994).

The analysis on the relations produced by 5 year olds shows that on the first dimension (explaining 85% of the total variance) superordinate level concepts, characterized by taxonomic relations, differ from subordinate relations characterized by thematic relations. On the second dimension (explaining 15% of the variance), attributive relations, that characterize basic level concepts, differ from evaluative relations.

Table 1: Five year olds. Percentage of the 4 kinds of relation at each hierarchical level.

Relation	Sup	Bas	Sub
Taxonomic	33	20	11
Thematic	48	61	69
Attributive	10	15	12
Evaluative	9	4	9

The analysis on the relations produced by 8 year olds shows that on the first dimension, which explains 97% of the total variance, superordinate level concepts, characterized by taxonomic relations, differ from both basic and subordinate level concepts characterized by thematic relations.

Table 2: Eight year olds. Percentage of the 4 kinds of relation at each hierarchical level.

Relation	Sup	Bas	Sub
Taxonomic	33	13	11
Thematic	34	53	49
Attributive	29	32	36
Evaluative	4	3	4

The analysis on the relations produced by 10 year olds shows that on the first dimension, which explains almost all the variance (99%), superordinate level concepts, characterized by taxonomic relations, differ from subordinate level concepts characterized by thematic relations.

Table 3: Ten year olds. Percentage of the 4 kinds of relation at each hierarchical level.

Relation	Sup	Bas	Sub
Taxonomic	30	15	12
Thematic	26	42	46
Attributive	32	32	32
Evaluative	12	11	9

As the percentages and the correspondence analyses suggest, at all the ages considered, the main difference between superordinate and lower level concepts does not depend on the production of attributive and evaluative relations, but on the production of taxonomic and thematic relations.

Superordinate level concepts elicit more taxonomic and less thematic relations than the lower level concepts. However, it is worth noting that superordinate level concepts elicit as many attributive relations as the other hierarchical levels. This could mean that perceptual information that is involved in attributive relations is conveyed not only by lower but also by superordinate level concepts. This result brings new evidence to the perceptual and action views of conceptual knowledge organization. Superordinate level concepts elicit mainly taxonomic relations at the subordinate level, i. e. instantiations (Heit & Barsalou, 1996), (98%, 99%, and 97% in 5, 8, and 10 year olds respectively), thus showing their 'plural force' (Markman, 1985; 1989; Murphy & Wisniewski, 1989). The same is found also in basic level concepts (88%, 72%, and 76% respectively), though the percentage of instantiations decreases consistently. Subordinate level concepts, instead, elicit mostly items at the superordinate level (55%, 53%, and 52% respectively).

To test hypothesis 2 a Correspondence Analysis was performed on the 4 kinds of relation crossed with the age levels. The first dimension, explaining 76% of the variance, shows the difference between 5 year olds, who produce mostly thematic relations, and 10 year olds who produce mostly attributive relations. The far less relevant second dimension, explaining 24% of the variance, shows the difference between 8 and 10 year olds as these last produce evaluative relations (see Figure 1).
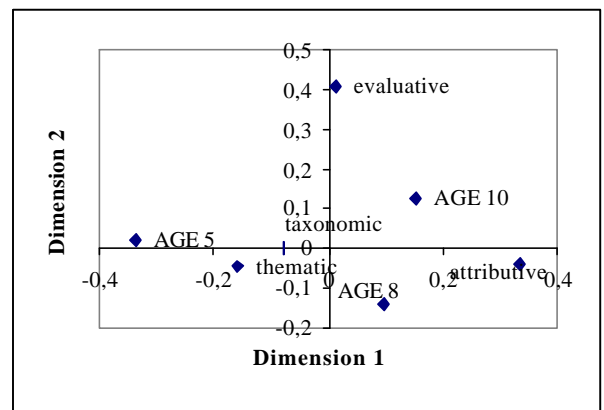

Figure 1: Correspondence Analysis on the 4 kinds of relation at each age level. Dimension 1 = 76% - Dimension 2 = 24%.

Even though the production of thematic relations decreases with age, at all the age levels the production of thematic relations outnumbers that of the other relations, while that of taxonomic relations does not consistently change (see Table 4). Thus, there seems to be no evidence of a thematic - to - taxonomic shift.

Furthermore, the production of perceptually grounded relations, i.e. attributive relations, increases consistently from 5 to 8 years.

Table 4: Percentage of the 4 kinds of relation produced at each age level.

Relation	Age 5	Age 8	Age 10
Taxonomic	23	20	19
Thematic	57	45	38
Attributive	12	32	32
Evaluative	8	4	10

This last result can be interpreted in the light of the growing analytical attitude children develop with schooling. The production of evaluative relations drops in 8 year olds and then increases again in 10 year olds.

Experiment 2

Experiment 2 was a replica of Experiment 1 but with adult participants and hence with slight variations. The aim was to test whether the trends found in Experiment 1 in 10 year old children are maintained in adults.

Method

Participants Two hundred students of the University of Bologna volunteered for their participation.

Materials Twenty-seven concepts were selected; each presented at the 3 hierarchical levels.

Procedure The procedure was the same as in Experiment 1 with minor adaptations for the adult participants. The task was not presented as a game and participants were allowed to write associations of associations. When presented with 'flower', for example, they could think of 'geranium' and had to write this word linked to 'flower'. If 'geranium' made them think of 'vase', they had to write 'vase' linked to 'geranium'. Thus, it was possible to distinguish between direct and indirect associations elicited by the given concept nouns. Participants could produce as many associations as they wanted in a maximum time of 5 minutes for each concept. Only direct associations were analyzed in this research

Coding The coding procedure and codes were the same as those used in Experiment 1. The two judges solved 8% cases of disagreement after brief discussion.

Data analysis and results

In order to test hypothesis 1, the percentages of the 4 kinds of the produced relations were computed for each hierarchical level of the concept-nouns (see Table 5). A Correspondence Analysis was performed on the frequencies of the relations produced crossed with the hierarchical levels of the concept-nouns. On the first dimension, explaining almost all the variance (98%), superordinate level concepts, that elicit taxonomic relations, differ from subordinate level concepts that elicit thematic relations.

Table 5: Adults. Percentage of the 4 kinds of relation at each hierarchical level.

Relation	Sup	Bas	Sub
Taxonomic	30	19	15
Thematic	29	37	42
Attributive	21	21	23
Evaluative	20	22	21

Both percentages and Correspondence Analysis replicate the same pattern of results as that found in children. Superordinate level concepts elicit more taxonomic relations and less thematic relations than lower level concepts. Again, attributive relations are elicited in the same proportion by superordinate level concepts as by lower level concepts.

Comparison between Experiment 1 and 2

In order to test hypothesis 2, the relations produced by children at the different age levels and by adults were compared.

As Figure 2 shows, the production of thematic relations gradually decreases between 5 and 10 years, and then it increases again. It is also worth noting that thematic relations are the most frequently produced by both children and adults. The production of taxonomic relations, instead, is more stable across the age levels than that of thematic relation. A greater variability is found in the production of attributive relations.
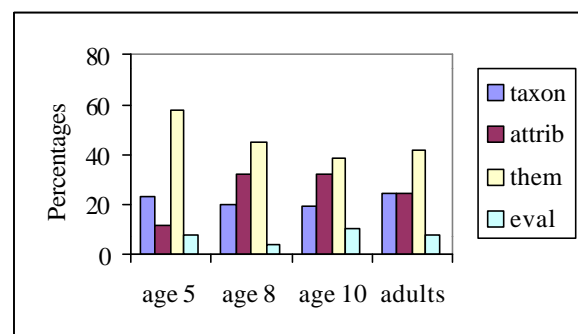

Figure 2: Percentage of the 4 kinds of relations at each age level.

A Correspondence Analysis was performed crossing the 4 groups of relations produced with the 4

different age levels (children aged 5, 8, and 10, and adults). The first dimension (explaining 67% of the total variance) shows the difference between 5 year olds, who produce thematic relations, and 10 year olds who produce attributive relations. On the second dimension (explaining 24% of the variance) both 5 and 8 year olds who produce attributive and thematic relations, differ from 10 year olds who produce taxonomic relations (see Figure 3). In this analysis adult's productions have no weight; this means that the pattern of relations they produce does not differ from that produced by children.
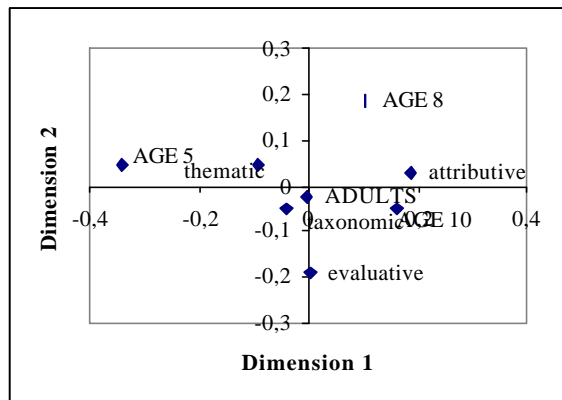

Figure 3: Correspondence Analysis on the 4 kinds of relations at each age level. Dimension 1 = 67%; Dimension 2 = 24%

General Discussion

The results verify the two hypotheses set forth at the beginning and support perceptual and action-based views of conceptual organization. They show that:

1. At each considered age, superordinate, basic and subordinate level concepts convey attributive, i. e. perceptually grounded, information. Such finding is consistent with the view advanced by Smith & Heise (1992) and Jones & Smith (1998) that perceptual properties are relevant in distinguishing between different kinds of superordinate level concepts. For example, both textural information and the difference between biological and non-biological movement help to distinguish between very general superordinate concepts such as artifacts and natural kind concepts.

The fact that superordinate level concepts convey more taxonomic and less thematic and contextual information than lower level concepts can be a consequence of the instantiation principle (Heit & Barsalou, 1996). The activation of superordinate level concepts elicit information about their exemplars thanks to their eliciting both attributive relations and instantiations of the subordinate kind. This result is consistent with the widely acknowledged result that superordinate level concepts activate their exemplars

(Callanan & al., 1994; Markman, 1985; 1989; Murphy & Wisniewski, 1989).

2. Contextual and thematic information plays a relevant part in organizing knowledge not only in children but also in adults. There is no evidence of a shift from taxonomic - to - thematic knowledge organization at least using a production task, as is the case in this study. In fact, the production of taxonomic relations does not change across the age levels. At all the ages considered, concepts convey more thematic than taxonomic information while the weight of attributive information becomes more relevant with age in shaping conceptual knowledge. This finding is supported also by recent evidence on the lack of a consistent preference for either thematic or taxonomic relations by pre-school children (Obsborne & Calhoun, 1998; Waxman & Namy, 1997) and on conceptual flexibility and variability (Smith & Samuelson, 1997).

This research shows that the cognitive economy principle, resting on a hierarchical organization of taxonomic relations, is not able to handle the way conceptual knowledge is really organized (for a similar conclusion see Sloman, 1998). The cognitive economy principle has to be revised so that it can handle all the nuances knowledge inherits from our complex dealings with the environment. This does not mean that abstraction has no part in knowledge organization, it only means that even abstract knowledge originates from direct experience.

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