Categorization by schema relations and perceptual similarity in 5-year-olds and adults: A study in vision and in audition

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Abstract

This research explores the way in which young children (5 years of age) and adults use perceptual and conceptual cues for categorizing objects processed by vision or by audition. Three experiments were carried out using forced-choice categorization tasks that allowed responses based on taxonomic relations (e.g., vehicles) or on schema category relations (e.g., vehicles that can be seen on the road). In Experiment 1 (visual modality), prominent responses based on conceptually close objects (e.g., objects included in a schema category) were observed. These responses were also favored when within-category objects were perceptually similar. In Experiment 2 (auditory modality), schema category responses depended on age and were influenced by both within- and between-category perceptual similarity relations. Experiment 3 examined whether these results could be explained in terms of sensory modality specializations or rather in terms of information processing constraints (sequential vs. simultaneous processing).

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Introduction

Perceptual and conceptual categories

A substantial amount of research has been carried out examining how categories develop and how they mediate our interactions with the world; however, the question of whether children’s perceptual and conceptual categories tap into different kinds of representational systems has not yet been answered. It has been shown that 1-year-olds are capable of forming both perceptual and conceptual categories and that very young infants can acquire categories using some kind of perceptual analysis mechanism. More precisely, by 3 to 4 months of age infants are capable of discriminating between basic-level objects (Eimas & Quinn, 1994; Quinn & Eimas, 1996), and by 1 year of age they can also form global concepts by learning characteristic properties. For example, McDonough and Mandler (1998) used an inductive generalization task to demonstrate that 9- and 11-month-olds can generalize properties (e.g., drinking [modeled on a dog toy]) within the appropriate domain (generalizations to other animals but not to vehicles). At this age, infants begin to focus on objects in the world through interpretative schemas.

For some authors, these different categorization abilities can be explained by only one kind of categorization process (Madole & Oakes, 1999; Quinn & Eimas, 2000). Infants first consider the perceptual features of objects before gradually considering more conceptual attributes (Rakison & Butterworth, 1998). Category representations then develop gradually through a process of quantitative enrichment.

Alternative hypotheses claim that perceptual and conceptual categories refer to different organizations. For example, Mandler (2000) considered that concepts or categories based on meaning are formed through a redescription of perceptual inputs. This process produces output representations called “image schemas.” Similarly, Hudson and Nelson (1983) described early conceptual representational systems in terms of scripts or event schemas. These representations, which emerge by 2 years of age, are organized spatially and temporally (e.g., the event of breakfast) and do not depend on the detection of perceptual invariants. Event schemas play an important role in the development of categorization because they include objects that play similar roles. These objects, which form “slot-filler” categories, help children to understand taxonomic conceptual organizations.

In summary, previous research has considered three types of categorical organization: perceptual, conceptual (based on schemas [spatial and/or temporal contiguity]), and taxonomic (same kind of object). How children use and link these different representations when they classify objects is an important theoretical question. While describing the role of

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1 In perceptual categories, the equivalences between objects concern only perceptual features. In conceptual categories, the equivalences are based on knowledge.

2 In this article, the term “schema” is used in a broad sense to refer to a representation that includes objects that can be seen in the same place. This term is used both for situational schemas, defined by spatial contiguity relations (e.g., the schema of the school), and for event schemas, defined by spatial and temporal contiguity relations (e.g., the event schema or script of breakfast).

3 A taxonomic category (foods) includes the same kinds of objects. When the taxonomic category is also defined by the situation in which the objects occur (breakfast foods), previous research has used the terms “slot-filler” category (Nelson, 1983) and “script” category (Nguyen & Murphy, 2003). Because the current authors consider both situational schemas and scripts, we use the more general term “schema category.”
slot-filler categories, Nelson (1983) focused on the relations between event schemas and taxonomic knowledge.

Many other studies have focused on the relations between perceptual and taxonomic organizations by examining how preschool children consider perceived attributes when using taxonomic representations. In property generalization tasks, Gelman and Markman (1986, 1987) showed that young children (3–4 years of age) generalize nonobvious properties on the basis of category labels rather than on the basis of perceptual similarity. Importantly, the consideration of category labels was increased when perceptually similar stimuli were used. In forced-choice sorting tasks (Golinkoff, Shuff-Bailey, Olguin, & Ruan, 1995; Imai, Gentner, & Uchida, 1994), young children use new labels to refer to objects that are similar in shape, whereas older children (by 5 years of age) and adults use them to refer to objects that are taxonomically related. This highlights a shift from the consideration of perceptual factors toward the consideration of taxonomic representations. It should be noted that this research looks at very specific abilities as concepts are linked to additional language inputs (labels), suggesting that perceptual cues and labels do not operate independently. No information, however, was given on the relation between perceptual and conceptual features when no lexical inputs are available.

The lack of experimental data is even more striking if we consider the question of the relation between schemas and perceptual factors. In a given schema, a number of perceptual similarity relations are available, especially between objects that play the same role or that form a slot-filler or schema category (e.g., two pets). Until now, researchers have not looked at whether these perceptual relations help in the processing of schema categories. One reason is that schema-based representations are generally described in terms of easily and primarily available conceptual structures (Inhelder & Piaget, 1964; Nelson, 1983). With the adoption of such a theoretical position, the consideration of possible facilitation due to perceptual factors is no longer interesting. However, it is important to note that young children are not always strongly interested in schema or script representations (Scott, Serchuk, & Mundy, 1982; Waxman & Namy, 1997). Furthermore, in some situations, the consideration of these representations has been found to increase throughout development. For example, Lucariello, Kyritzis and Nelson (1992) used a forced-choice categorization task to demonstrate that the preference for slot-filler responses over taxonomic responses is higher in 7-year-olds than in 4-year-olds. Furthermore, there is now evidence that the relations between objects within a given scene or schema play an important role in categorization by adults and that these relations may help to provide conceptual coherence (Lin & Murphy, 2001; Ross & Murphy, 1999). These results suggest that schematic organization is unlikely to be primitive; therefore, the facilities for processing categories based on schema or event knowledge may have been overestimated in a lot of research.

This has led us to reevaluate the role of perceptual similarity relations by examining the extent to which these relations can help to process the schema category structure. We believed that such data would be useful for understanding the link between perceptual factors and conceptual knowledge in children’s and adults’ responding (establishing a comparison with what has been proposed for infants [Mandler, 2000; Quinn & Eimas, 2000]).

**Information processing constraints and sensory modality effects**

An original feature of this work is that perceptual similarity relations are defined using either visual or auditory cues. In everyday life, vision and audition play central roles in the
multimodal perception of objects as the two modalities are adapted for processing distant characteristics. As adults, we display a wide array of multisensory abilities, especially in the area of auditory–visual perception. Speech perception is an excellent example of a fundamental event that elicits both auditory and visual modalities. The well-known McGurk effect illustrates how we combine auditory and visual information when perceiving speech units (MacDonald & McGurk, 1978). Multimodal perception involving vision and audition is not limited to the domain of language; this type of effect has also been demonstrated with nonverbal stimuli (Saldana & Rosenblum, 1993). In many situations, auditory cues help us to perceive the visual and structural characteristics of objects. Similarly, the presence of visual cues facilitates the identification of audible features.

Given the multimodal nature of perception, we focused on categorization skills involving vision (Experiments 1 and 3) or audition (Experiment 2). Previous research has identified a number of similarities in the construction of visual and auditory representations. For example, in both modalities the perceptual and cognitive systems have often been described as working in concert. It has been observed that the semantic content of a stimulus affects the perceptual qualities of a scene, and it has been suggested that such top-down information processing is brought into play in vision (Johnson & Mervis, 1997) and in audition (Slaney, 1997). Our research took a different approach in that we tried to determine whether perceptual factors affect the semantic or knowledge-based analysis of a situation. We then investigated complementary bottom-up information processing. This approach has led us to highlight possible effects linked to processing constraints that are very different in vision and in audition. Vision involves comparing simultaneously processed stimuli, whereas audition requires sequential processing. These sequential/simultaneous processing aspects influence the way in which physical and knowledge-based attributes are weighted. Therefore, the study of these aspects is important for understanding how perceptual and conceptual organizations are related. According to Lin and Murphy (2001), if during a categorization task the stimuli are processed in isolation, an adult’s consideration of physical similarities will increase and the influence of thematic relations will decrease (for a description of these effects in a lexical learning context, see also Rey & Berger, 2001).

Based on these considerations, we postulated that categorization is perceptually driven, especially in the case of audition (Experiment 2) but also in the case of vision when the stimuli must be processed sequentially (Experiment 3).

The current experiments

To examine the differential weighting of perceptual and conceptual cues during categorization, a forced-choice categorization procedure was used with children and adults. For each item, a target (pet) and two comparison objects (another pet and a farm animal) were presented. The participants were told to choose the comparison object “that goes best with” the target. Although both comparison objects were from the same taxonomic category as the target (two kinds of animals), only one (the conceptually close object) was from the same schema.

Comparison objects also varied according to their perceptual similarity with the target. The distance in terms of perceptual similarity between the target and comparison objects was measured by multidimensional scaling analysis. Previous studies on the effect of perceptual attributes in categorization have measured perceptual similarity relations roughly.
Moreover, in these studies, following subjective scaling, perceptually similar and perceptually dissimilar stimuli were defined within a given item, meaning that the perceptual distances between the standard and each comparison object could vary significantly from one item to another. The use of multidimensional scaling analysis allows the selection of stimuli that are separated by homogeneous distances.

Experiment 1 tested visual representations of objects, whereas Experiment 2 looked at auditory representations of the same objects. The two experiments had different presentation constraints in that the stimuli appeared at the same time in Experiment 1 (simultaneous presentation characterizing the visual modality) and sequentially in Experiment 2 (sequential presentation characterizing the auditory modality). Experiment 3 used a nonecological categorization context in which the visual representations of the objects were presented sequentially so that the visually processed stimuli needed to be compared using stored information. This procedure was chosen to determine whether differences in performance patterns between vision (Experiment 1) and audition (Experience 2) would still occur if the processing differences between the two modalities were reduced. We then tried to isolate factors related to the nature of the sensory modality from those related to information processing constraints.

The experiments were designed to further our understanding of how schema categories are weighted in children’s and adults’ concepts. Rather than contrasting taxonomic and contiguity relations (as has been done in previous research), our objective was to determine the extent to which the consideration of contiguity relations can be influenced by perceptual information. This research should also improve our understanding of how perceptual and conceptual organizations are linked outside a lexical learning context and under different sensory modalities. Because such experiments require participants to have sufficient experience of objects (experience of objects is needed for detecting schema-based relations), we decided to study 5-year-olds. This age also corresponds to the emergence of slot-filler categories (Nelson, 1983).

**Experiment 1**

Previous developmental research has provided information about the roles of perceptual features and schemas in the construction of taxonomic representations. Categorization preferences have been examined using forced-choice categorization tasks that compare different kinds of relations: taxonomic versus thematic (Markman & Hutchinson, 1984), taxonomic versus perceptual (Baldwin, 1992), taxonomic versus thematic versus perceptual (Golinkoff et al., 1995; Imai et al., 1994). Studies based on these methods have shown that young preschoolers (3–4 years of age) often categorize according to thematic relations. Such thematic responses tend to be replaced by perceptual (and possibly taxonomic) responses when lexical cues are available. In older children and adults, taxonomic classifications generally were observed.

The current experiment was designed to examine how perceptual features and schemas can be linked in a categorization task that uses taxonomically related objects (e.g., different kinds of animals). Lucariello and Nelson (1985) reported some interesting results relating to the role of schema categories. They found that when slot-filler relations were available in a forced-choice categorization task, 4- and 7-year-olds demonstrated a preference for slot-filler responses over taxonomic responses. More important, the frequency of slot-filler responses increased with age. These results showed that participants learn to use additional
information based on schemas or event structures. Recently, some authors have suggested that strong thematic relations may play an important role in categorization by adults (Lin & Murphy, 2001; Ross & Murphy, 1999).

Surprisingly, there are no available data on facilitation due to perceptual factors when a schema structure is being processed (although such facilitation has been considered to explain taxonomic responses [Golinkoff et al., 1995; Imai et al., 1994]). Such data are necessary for establishing how perceptual and conceptual organizations are related. The aim of our experiment was to establish whether the consideration of schema categories increases when additional perceptual similarity relations are available. This question was examined from a developmental point of view using a forced-choice categorization task involving visually presented stimuli. We then examined the differential weighting of perceptual information and schema information in children and adults. The results of previous work led us to advance the hypothesis that schematic (as opposed to perceptive) links are weighted more highly in adults than in children. In addition, we asked whether, in each age group, the ability to respond according to schema categories is dependent on perceptual factors. Such data would help us to understand how children and adults link perceptual and conceptual features in their categorization responding.

**Method**

**Participants**

The participants were 16 children between the ages of 5 years 0 months and 6 years 1 month (mean age = 5 years 4 months) and 16 adults. The children were pupils at a preschool in Chambéry, France, and the adults were students at the University of Savoie. Informed consent was obtained from the parents of the children and from the adult participants.

**Materials and procedure**

**Stimuli**

In each of six stimulus sets (items), four triads composed of one target and two comparison objects were constructed. The targets and comparison objects chosen for each item are presented in Table 1. Some of the items were natural objects or elements (Items 1 and 4), and others were artifacts (Items 2, 3, 5, and 6). It should be noted that most of our artifact stimuli were vehicles. The choice was made to take into account the difficulty of identifying

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Description of the sets of visual stimuli for each item</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target</strong></td>
<td><strong>Slot-filler</strong></td>
</tr>
<tr>
<td><strong>Similar</strong></td>
<td><strong>Dissimilar</strong></td>
</tr>
<tr>
<td>Item 1: Dog</td>
<td>Puppy</td>
</tr>
<tr>
<td>Item 2: Alarm clock</td>
<td>Telephone</td>
</tr>
<tr>
<td>Item 3: Plane</td>
<td>Rocket</td>
</tr>
<tr>
<td>Item 4: Rain</td>
<td>Flash of lightning</td>
</tr>
<tr>
<td>Item 5: Car</td>
<td>Truck</td>
</tr>
<tr>
<td>Item 6: Fire truck</td>
<td>Ambulance</td>
</tr>
</tbody>
</table>
objects from auditory cues. In everyday life, many objects can be recognized using both visual and auditory cues, but very few can be identified using auditory cues only (by the time children are 1–2 years old, they can recognize planes, cars, and motorbikes on the basis of auditory cues only). Although vehicle stimuli were frequently used, participants needed to consider diverse knowledge-based representations; in giving a “schema category response,” it is first and foremost the context associated with the vehicle that must be processed (e.g., idea of a land vehicle, idea of an air vehicle).

In each triad, one comparison object (i.e., the taxonomic object) had only a taxonomic relation with the target; the second comparison object (i.e., the schema category object) had both a taxonomic relation and a contiguity relation with the target. For example, if the target object was an airplane, possible comparison objects were (a) a car (another vehicle [taxonomic relation]) and (b) a helicopter (a vehicle showing a contiguity relation with the target given that both can be seen in the same place [schema category]). In addition, the comparison objects could be perceptually close to the target or distant from it. For each target, the triad was completed with two comparison objects as follows:

Triad Type A: same schema, perceptually similar/different schema (same taxonomy), perceptually similar
Triad Type B: same schema, perceptually dissimilar/different schema (same taxonomy), perceptually dissimilar
Triad Type C: same schema, perceptually similar/different schema (same taxonomy), perceptually dissimilar
Triad Type D: same schema, perceptually dissimilar/different schema (same taxonomy), perceptually similar.

The participants were presented with the three stimuli and were told, “Look at this [pointing to the target]. Find the one [pointing to the comparison objects] that goes with it best.” The three stimuli remained in place until the participants responded. The “go best” instruction, which allowed either perceptual or conceptual responses, was used because the aim of the research was to determine the participants’ preferences. Each participant was presented with 24 triads (6 stimulus sets × 4 triad types) in a random order. Right and left positions for the schema and taxonomic comparison objects were also varied randomly.

**Stimulus selection procedure**

We used multidimensional scaling (MDS) analysis for controlling the perceptual relations between stimuli (Kruskal, 1964a, 1964b; Shepard, 1962a, 1962b). The objective of MDS analysis is to reveal relations between a set of stimuli by representing them in a geometric space in such a way that the distances between the stimuli reflect their relative perceptual dissimilarities. A set of 29 images was chosen. For each item, 35 adults were recruited. All of the pairs were presented, and the participant’s task was to compare the pairs of stimuli and directly rate their degree of perceptual dissimilarity on a scale from 1 (very similar) to 9 (very dissimilar). The perceptual nature of the rating was emphasized during the instruction. A dissimilarity matrix was calculated by averaging the results for all

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4 To compare categorization skills in vision (Experiments 1 and 3) and audition (Experiment 2), objects identifiable in both modalities must be used.
of the participants. This was used as input to the Statistica multidimensional scaling program. The schema category comparison objects for each item were selected by systematically choosing the two schema objects that had the smallest and greatest metric distances from the targets. The mean distances from the targets for the six items were 0.72 for the perceptually close objects and 1.36 for the perceptually distant objects. Similarly, the taxonomic comparison objects for each item were selected by systematically choosing the taxonomic objects with the smallest and greatest metric distances from the targets. The mean distances from the targets for the six items were 1.47 for the perceptually close objects and 1.71 for the perceptually distant objects.

Results and discussion

The mean numbers of schema-based responses as a function of age and condition (note that taxonomic responses are complementary) are shown in Table 2.

An analysis of variance (ANOVA) was conducted on the number of times each participant chose the schema category response. The between-subjects variable was age (5 years old or adult). The within-subjects variables included (a) the perceptual similarity between the schema comparison object and the target and (b) the perceptual similarity between the taxonomic comparison object and the target. The ANOVA revealed a significant effect of the perceptual relations between the target and the schema comparison objects, $F(1,30)=13.89$, $p<.001$. Schema category responses were more frequent with similar schema comparison objects ($M_D=5.36$) than with dissimilar ones ($M_D=4.99$). No other main effect or interaction was significant. Importantly, the schema category responses did not depend on age or on the similarity between the taxonomic comparison objects and the target. Additional $t$ tests showed that schema category scores were always above chance level ($p<.01$) both in children, $t(15)=9.80$, $t(15)=11.72$, $t(15)=6.73$, and $t(15)=8.48$ for Triad Types A, B, C, and D, respectively, and in adults, $t(15)=13.03$, $t(15)=13.93$, $t(15)=9.06$, and $t(15)=9.60$ for Triad Types A, B, C, and D, respectively. These results show that schema category responses were always more frequent than taxonomic responses.

Table 2

Mean numbers of responses based on schema category (vs. taxonomic categories) in Experiment 1 (vision/simultaneous presentation), Experiment 2 (audition), and Experiment 3 (vision/sequential presentation)

<table>
<thead>
<tr>
<th></th>
<th>Schema object: perceptually similar</th>
<th>Schema object: perceptually dissimilar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Taxonomic similar</td>
<td>Taxonomic dissimilar</td>
</tr>
<tr>
<td>Experiment 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-year-olds</td>
<td>5.06 (0.85)</td>
<td>5.38 (0.81)</td>
</tr>
<tr>
<td>Adults</td>
<td>5.63 (0.81)</td>
<td>5.38 (0.72)</td>
</tr>
<tr>
<td>Experiment 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-year-olds</td>
<td>3.89 (1.20)</td>
<td>4.16 (1.21)</td>
</tr>
<tr>
<td>Adults</td>
<td>4.42 (1.07)</td>
<td>5.32 (0.75)</td>
</tr>
<tr>
<td>Experiment 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-year-olds</td>
<td>5 (0.82)</td>
<td>5.38 (0.72)</td>
</tr>
<tr>
<td>Adults</td>
<td>5.5 (0.73)</td>
<td>5.5 (0.63)</td>
</tr>
</tbody>
</table>

Note. Standard deviations are in parentheses.
The results of this experiment present a coherent picture. Children and adults uniformly categorized the stimuli using conceptual similarity relations. In all experimental conditions, a consideration of the schema organization occurred because schema category responses were always prominent. Importantly, schema category relations were considered even when the schema relations were pitted against perceptual similarity (Triad Type D). However, perceptual similarity relations influenced the categorization profiles in that schema category responses were more frequent when schema comparison objects that were perceptually similar (vs. dissimilar) to the target were used. Such results are consistent with the view that categorizations based on perceptual factors and those based on conceptual factors do not operate independently.

Nevertheless, this conclusion must be treated with caution because restrictions on the influence of perceptual factors were observed. First, schema category responses did not depend on perceptual similarity relations when these relations involved targets and taxonomic objects (strong perceptual effects should have been observed for both within- and between-category relations). Second, the consideration of perceptual similarity relations did not vary with age. One possible explanation for these findings could be a relative facility for processing the schema structure in the context of the task proposed. Such a facility could have precluded the consideration of some aspects of perceptual appearance (i.e., relative to the taxonomic object). It could also explain the absence of developmental effects. An important question is whether perceptual similarity factors influence the conceptual categorization of the stimuli more clearly in contexts that reduce the salience of the schema structure (or that increase the salience of perceptual relations). This question was examined in Experiment 2, which looked at auditory stimuli.

**Experiment 2**

Vision and audition often work in concert for processing environmental cues (Saldana & Rosenblum, 1993). As a preliminary approach to answering the question of how these sensory modalities interact for processing such cues, we need to consider the way in which participants categorize auditory stimuli (compared with what has been observed for visual stimuli). In auditory presentations, the characteristics of the stimuli must be stored in the memory so that they can be used for performing comparisons. In such a context, individuals may prefer to base their comparisons on information that is the least costly or most simple to process. Therefore, auditory constraints may reduce the salience of conceptual organization (cost linked to the memorization and activation of knowledge relating to the schema). Conversely, participants could more easily base their comparisons on perceptive traces and give responses according to perceived attributes. This hypothesis is consistent with Lin and Murphy’s (2001) description in which they suggested that, when performing a categorization task, processing of the stimuli in isolation would increase the consideration of physical similarities instead of thematic relations.

To complete our research within the theoretical context outlined here, we wanted to determine whether schema category responses would nevertheless be prominent in the case of auditory stimuli. We also examined whether the frequency of these responses depends on perceptual similarity factors and age. Given the auditory constraints described previously, we predicted that perceptual information would have a substantial influence in audition. If this were found to be the case, our aim was to determine whether schema category
responses would depend on the perceptual distances between the target and both the schema comparison object (i.e., facilitation due to within-category resemblance [demonstrated in Experiment 1]) and the taxonomic comparison object (i.e., facilitation due to between-category dissemblance [not shown in Experiment 1]).

Finally, we predicted that children and adults would show different patterns of categorization due to different storage capabilities. These capabilities (involved in audition due to the sequential characteristics of processing) should favor schema category responses (see previous description).

**Method**

**Participants**

The participants were 19 children between the ages of 5 years 0 months and 6 years 2 months (mean age = 5 years 6 months) and 19 adults. The children were pupils at a preschool in Chambéry, and the adults were students at the University of Savoie. Informed consent was obtained from the parents of the children and from adult participants.

**Materials and procedure**

**Stimuli**

The objects considered in this experiment corresponded to those used in Experiment 1 but were represented using auditory cues rather than visual cues. The targets and comparison objects (sounds corresponding to the visual pictures of Experiment 1) are presented in Table 3.

The triad types and procedure also corresponded to those used in Experiment 1. Before performing the categorization task, we ensured that the participants could identify the 24 objects on the basis of their auditory representation. Each sound was presented, and the participant was instructed to name the corresponding object. The correct name was given if the participant failed to respond or if the response was incorrect. The identification phase stopped when all of the objects had been named correctly.

The categorization task was then administered. A major difference compared with Experiment 1 was that the stimuli used in a given trial were presented sequentially (constraints of auditory processing). The participants were first presented with the target

<table>
<thead>
<tr>
<th>Target</th>
<th>Slot-filler Similar</th>
<th>Dissimilar</th>
<th>Taxonomic Similar</th>
<th>Dissimilar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 1: Dog barking</td>
<td>Puppy barking</td>
<td>Cat meowing</td>
<td>Seal barking</td>
<td>Wolves howling</td>
</tr>
<tr>
<td>Item 2: Alarm clock ringing</td>
<td>Telephone ringing</td>
<td>Clock ticking</td>
<td>Boat siren</td>
<td>Ambulance siren</td>
</tr>
<tr>
<td>Item 3: Plane flying</td>
<td>Fighter jet taking off</td>
<td>Helicopter flying</td>
<td>Truck on highway</td>
<td>Car passing</td>
</tr>
<tr>
<td>Item 4: Raining</td>
<td>Thunderstorm with rain</td>
<td>Blizzard</td>
<td>Shower sequence</td>
<td>Waterfall</td>
</tr>
<tr>
<td>Item 5: Car on highway</td>
<td>Truck on highway</td>
<td>Motorbike starting, leaving, returning, stopping</td>
<td>Plane flying</td>
<td>Diesel train</td>
</tr>
<tr>
<td>Item 6: Horn</td>
<td>Ambulance siren</td>
<td>Car on highway</td>
<td>Boat siren</td>
<td>Alarm clock ringing</td>
</tr>
</tbody>
</table>
object and were told, “Listen to this [pointing to the nonsense icon representing the target]. You will hear two other sounds corresponding to two different objects. Find the one that goes with it best” (nonsense icons were used to represent the comparison objects). The physical duration of the sounds varied from 1 to 8 s. This variation resulted from the time needed to recognize the sound (i.e., some sounds needed to be processed a long time before they were recognized). The interstimulus interval was 1 s. Participants were also informed that they could listen to each sound as often as they wished before responding. In all other respects, the procedure was similar to that used in Experiment 1.

**Stimulus selection procedure**

As in Experiment 1, an MDS analysis was used for controlling the perceptual relations between stimuli. The 35 adult participants performing the visual comparisons in Experiment 1 were also asked to rate the degree of dissimilarity between the corresponding sound pairs. The schema category comparison objects for each item were selected by systematically choosing the two schema objects that had the smallest and greatest metric distances from the targets. The mean distances were 0.78 for the perceptually close objects and 1.80 for the perceptually distant objects. Similarly, the taxonomic comparison objects for each item were selected by systematically choosing the taxonomic objects with the smallest and greatest metric distances from the targets. The mean distances for the perceptually close and distant objects were 0.99 and 1.61 respectively.

**Results and discussion**

The mean numbers of schema category responses as a function of age and condition are presented in Table 2.

An ANOVA was carried out on the number of times each participant chose the schema category response. The between-subjects variable was age (5 years old or adult). The within-subjects variables were (a) the perceptual similarity between the schema comparison object and the target and (b) the perceptual similarity between the taxonomic comparison object and the target. The ANOVA revealed a significant effect of age, $F(1,36) = 17.24, p < .001$, with more schema category responses in adults ($M = 4.32$) than in children ($M = 3.54$). The ANOVA also revealed a significant effect of the perceptual relations between the target and the schema comparison object, $F(1,36) = 37.87, p < .0001$. Schema category responses were more frequent with similar schema comparison objects ($M = 4.44$) than with dissimilar ones ($M = 3.43$). The effect of the perceptual relations between the target and the taxonomic objects was also significant, $F(1,36) = 10.89, p < .003$. Higher scores were observed for the taxonomically dissimilar objects ($M = 4.24$) than for the taxonomically similar objects ($M = 3.64$).

Additional $t$ tests were performed to compare the actual proportion of schema category responses with the proportion predicted by chance. In children, scores above chance level ($p < .01$) were observed only when similar schema comparison objects were used, $t(18) = 3.29$ and $t(18) = 4.28$ for Triad Types A and C, respectively. With dissimilar schema comparison objects, $t$ scores were not significant, $t(18) < 1$ and $t(18) = 1.01$ for Triad Types B and D, respectively. In adults, scores above chance level ($p < .01$) were observed when similar slot-filler comparison objects were used, $t(18) = 5.91$ and $t(18) = 12.97$ for Triad Types A and C, respectively. Scores were also above chance level ($p < .01$) when both the schema and taxonomic comparison objects were perceptually far from the target,
$t(18) = 4.49$ for Triad Type B. In adults, the only situation precluding a preference for schema category responses was when the perceptual salience was low for the schema relation and high for the taxonomic relation, $t(18) = 1.55$ for Triad Type D.

**Comparison with visually processed stimuli**

Because the items used in Experiment 2 corresponded to auditory representations of the pictures used in Experiment 1, we performed a complementary ANOVA to study whether schema category responses differed with regard to visual stimuli and to auditory stimuli. The sensory modality effect was analyzed by comparing data from Experiment 1 (vision) with data from Experiment 2 (audition). The main effect of this factor was significant, $F(1, 66) = 55.30, p < .000$, with more schema category responses in vision than in audition. The nature of the sensory modality also interacted with the perceptual relations between the target and the taxonomic comparison object, $F(1, 66) = 9.29, p < .004$.

The pattern of results obtained in the current experiment is consistent with the idea that it is quite difficult to categorize auditory-processed stimuli at a conceptual level. It was found that schema category responses were less frequent in children than in adults. Moreover, and contrary to what was seen in Experiment 1, these responses were not always prominent.

Our results also demonstrated that perceptual similarity relations play an important role in the use of schema categories by children and adults. The frequency of schema category responses increased when similar schema or dissimilar taxonomic comparison objects were used. In these cases, an influence of both within- and between-category perceptual factors was seen. Contrary to what was observed in Experiment 1, a general and clear consideration of perceptual factors was then demonstrated here. It could be that the relations between the perceptual and conceptual levels of categorization (Experiments 1 and 2) depend on the relative salience of the perceptual/conceptual information. Because perceptual factors are highly salient in audition (see theoretical introduction to Experiment 2 above), linkages between perceptual and conceptual organizations were clearly seen in Experiment 2. In terms of developmental effects, schema category responses were less frequent in children than in adults. It should be noted that perceptual facilitation for producing these responses did not vary according to age.

Next, we looked at the origin of the strong influence of perceptual information observed in this experiment. The explanations we propose focus on storage constraints. However, the explanation may be due to the characteristics of the auditory system; the auditory and visual systems could be adapted for analyzing different kinds of relations. To dissociate modality-specific preferences from processing constraints, we performed a third experiment using visual representations (as in Experiment 1) but with a sequential presentation of the stimuli (as in Experiment 2).

### Experiment 3

The fact that perceptual information has a more pronounced influence on schema category responses for auditory stimuli (Experiment 2) than for visual stimuli (Experiment 1) is

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A main effect of the perceptual relations between the target and the taxonomic comparison object was demonstrated in Experiment 2 (audition) but not in Experiment 1 (vision).
consistent with the idea that perception and conception do not call on separate and independent representational systems. Experiment 3 was used to investigate the origin of the differences observed between categorization skills performed using visual stimuli and those performed using auditory stimuli.

There are important differences between the ways in which visual and auditory stimuli are processed. As mentioned previously, visual stimuli can be compared simultaneously, whereas auditory stimuli are processed sequentially. Experiment 3 reproduced a nonecological categorization situation in which visual stimuli needed to be compared using stored information. This experiment was designed to determine the extent to which the differences in the results of the experiments on visual and auditory stimuli would be reproduced if the information processing differences between the two modalities were reduced. The experiment was carried out using the same pictures of objects as used in Experiment 1. Presentation of the stimuli was constrained to reduce the accessibility of conceptual cues, thereby increasing the accessibility of perceptual cues. In each trial, the stimuli were presented sequentially so that comparisons in the categorization task needed to be performed using stimulus characteristics stored in the memory.

**Method**

**Participants**

The participants were 16 children between the ages of 5 years 4 months and 6 years 2 months (mean age = 5 years 9 months) and 16 adults. The children were pupils from a preschool in Chambéry, and the adults were students at the University of Savoie. Informed consent was obtained from the parents of the children and from the adult participants.

**Materials**

The stimuli were the same as those used in Experiment 1; however, Experiment 3 was carried out under different processing constraints in that the three stimuli used in each trial were presented sequentially. Thus, the participants were first presented with the target object (as in Experiment 2). They were told, “Look at this [pointing to the target]. You will see two other objects (one after the other). Choose the one that goes with it best.” Each stimulus was presented for 2 s, with a 1-s interstimulus interval. As in the previous experiments, participants were told that they could see each object as often as they wished before giving their response. As in Experiments 1 and 2, the positioning of the comparison objects (either on the left-hand side of the screen or on the right-hand side of the screen) was varied randomly across the participants and conditions.

**Results and discussion**

The mean numbers of schema category responses as a function of age and condition are shown in Table 2.

An ANOVA was conducted on the number of times each participant chose the schema category response. The between-subjects variable was age (5 years old or adult). The within-subjects variables were (a) the perceptual similarity between the schema comparison object and the target and (b) the perceptual similarity between the taxonomic
comparison object and the target. The ANOVA revealed a significant effect of age, $F(1, 30) = 6.51$, $p < .02$, with more schema category responses in adults ($M = 5.28$) than in children ($M = 4.79$). The ANOVA also revealed a significant effect of the perceptual relation between the target and the schema comparison object, $F(1, 30) = 15.89$, $p < .001$. Schema category responses were more frequent with similar schema comparison objects ($M = 5.34$) than with dissimilar ones ($M = 4.73$). No other main effect or interaction was significant. Additional $t$ tests were performed showing that schema category responses were above chance level ($p < .01$) in each condition both in children, $t(15) = 10.00$, $t(15) = 13.24$, $t(15) = 4.31$, and $t(15) = 13.24$ for Triad Types A, B, C, and D, respectively, and in adults, $t(15) = 13.7$, $t(15) = 15.82$, $t(15) = 6.71$, and $t(15) = 15.82$ for Triad Types A, B, C, and D, respectively.

Comparison with auditorily processed stimuli

As in Experiment 2, we performed a further ANOVA to determine whether there was a difference in schema category responding for visual and auditory stimuli. The sensory modality effect was analyzed by comparing data from Experiment 2 (audition) with data from Experiment 3 (vision). The main effect of the sensory modality was significant, $F(1, 66) = 49.52$, $p < .000$, with more schema category responses for visual stimuli than for auditory stimuli. The type of sensory modality also interacted with the perceptual relations between the target and the taxonomic comparison object, $F(1, 66) = 10.64$, $p < .002$.

The results of this experiment show that the schema-based organization is critical for categorizing visual stimuli both in children and in adults. This result is consistent with the results of Experiment 1. When compared with auditory stimuli (Experiment 2), visual stimuli induce a high consideration of knowledge-based features, patterns that occur for both simultaneous and sequential presentations. As in audition, there was an effect of age; it was more difficult for children to reason on the basis of a conceptual organization than it was for adults. Although there was an overall majority of schematic responses to visual stimuli, the production of such responses by young children seems to be reduced in situations involving sequential processing. Finally, the patterns of perceptual resemblance observed here differed from those seen in Experiment 2 in that only the similarity relations between targets and schema comparison objects influenced the categorization responses. Thus, it appears that perceptual factors have a greater influence in determining schema-based responses to auditory stimuli than to visual stimuli.

General discussion

The experiments presented here were used to examine the consideration of schemas and perceptual relations in categorization tasks based on visual and auditory cues. Previous research using visual stimuli has examined the extent to which categorization responding of different age groups relies on schema or perceptual information. However, such research has not addressed the question of whether perceptual resemblances can help to process categories based on schema relations.

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A main effect of the perceptual relations between the target and the taxonomic comparison object was demonstrated in Experiment 2 (audition) but not in Experiment 3 (vision [using a sequential presentation]).
Our study examined perceptual facilitation to analyze the links between perceptual and conceptual organizations and, thus, to determine whether they refer to different and dissociated organizations (Mandler, 2000; Nelson, 1983; Quinn & Eimas, 2000). The experimental procedure was designed to (a) describe the relation between perceptual and conceptual organizations in the visual and auditory modalities and (b) explain and analyze the specificity of the categorization skills observed for each sensory modality. Such studies are important for several reasons. First, both visual and auditory cues are essential in the everyday multimodal perception of objects and events because they provide information about distant characteristics. Therefore, from an ecological point of view, it is important to determine whether auditory and visual cues influence categorization in the same way or in different ways. Second, the salience of perceptual cues is different in vision and in audition. Because of these salience differences, a comparison between these two modalities is interesting for examining the relations between percepts and concepts. More precisely, we studied whether categorization skills based on a schema category organization would depend on perceptual salience factors. This was found to be the case. The origin of the resulting modality-specific effects was the subject of Experiment 3, which examined the influence of sequential versus simultaneous information processing on categorization responding. The only difference between Experiments 1 and 3, both of which used visual stimuli, was that the stimuli were presented sequentially in Experiment 3 and simultaneously in Experiment 1. The procedures for Experiments 2 and 3 were identical except for the fact that auditory stimuli were used in Experiment 2 and visual stimuli were used in Experiment 3. Therefore, the results of Experiment 3 show the extent to which categorization responding is dependent on sensory specializations or on information processing characteristics.

We first consider categorization responding produced by (a) standard visual processing and (b) standard auditory processing. Perceptual similarity relations influence differently the consideration of perceptual cues in Experiments 1 (visual) and 2 (auditory). Indeed, in both experiments, schema category responses were more frequent when schema comparison objects that were perceptually similar (vs. dissimilar) to the target were used. However, in Experiment 2, additional effects were observed because schema category responses were also found to be more frequent when the taxonomic comparison objects (i.e., alternative responses) were perceptually dissimilar to the target. Such results (especially those of Experiment 2) are consistent with the view that categorizations based on perceptual factors and categorizations based on conceptual factors do not operate independently (Madole & Oakes, 1999; Quinn & Eimas, 2000).

However, there were also differences in the way in which the participants responded to visual and auditory stimuli in terms of categorization preferences. For visual stimuli, schema category responses were always above chance level both in children and in adults. The results for auditory stimuli were less clear-cut given that the prominence of these responses depended both on age and on the perceptual relations between the stimuli. The question now is to determine whether these observations could be explained by sensorial modality specialization or rather in terms of information processing constraints. This hypothesis is examined in this section.

When visual stimuli were presented sequentially (Experiment 3), we observed a developmental effect on the consideration of schema relations. This effect was not observed when the stimuli were presented simultaneously (Experiment 1). Thus, it appears that children are less able to mobilize knowledge for categorizing stimuli that are presented sequentially. In such a context, the stimuli must be stored in memory for performing comparisons. We
suggest that the storage of conceptual cues is more complex and requires more effort than does the storage of perceptual cues. This could explain why the children’s responses were more strongly related to perceptual factors in Experiment 3 than in Experiment 1.

We also considered the question of whether perceptual similarity relations can influence sorting based on conceptual knowledge. Analogous perceptual similarity effects were observed in Experiments 1 and 3; schema category responding increased when perceptually similar schema comparison objects were used but not when perceptually dissimilar taxonomic objects were used. These results suggest that the perceptual and conceptual levels of representations are partially related when performing a categorization task. In other words, although categorization responding involves within- and between-category comparisons (Bonthoux & Berger, 2001; Eimas & Quinn, 1994), only the within-category perceptual resemblance seems to increase the frequency of schema category responding. It is important to note that this result was obtained for visual stimuli both when the stimuli were processed simultaneously and when they were processed sequentially. Although processing constraints certainly determine the salience of perceptual information, it seems that they do not influence the way in which we relate perceptual and conceptual cues for categorizing.

The role of sensory modality can be examined by comparing the results of Experiments 2 and 3, both of which were performed using a sequential presentation, but Experiment 2 involved stimuli with auditory perceptual dimensions and Experiment 3 involved stimuli with visual perceptual dimensions. One of the most important findings of this study is that schema category responding is always prominent with visual stimuli but is not always prominent with auditory stimuli. More precisely, the prominence of these responses in Experiment 2 (audition) is dependent on both age and perceptual similarity factors. It seems that auditory processing increases the weighting of perceptual information and reduces that of conceptual knowledge. One reason could be the difficulty of storing conceptual cues in memory, resulting in a greater consideration of perceptual traces for performing a comparison.

Our experiments also showed that it is difficult to categorize auditory stimuli according to a schema organization, especially for children. However, it is unclear whether these difficulties are modality specific and/or related to processing constraints. A lack of experience with auditory stimuli would support a modality-specific hypothesis. Indeed, in the case of visual stimuli, we know that children have access to a large number of schema representations at an early age (Hudson & Nelson, 1983; Mandler, 2000). Children may have less well-defined representations of auditory stimuli due to a lack of experience.

Although this hypothesis is interesting, our results suggest that the lack of experience cannot be considered as the only factor explaining the children’s difficulties in processing a schema category structure in audition. Indeed, in our experiments, we solicited only knowledge linked to the context in which the object is encountered (contiguity). It is legitimate to consider that such knowledge is relatively basic and is easily accessible even in young children (Nelson, 1983).

We then must consider the storage constraints hypothesis. This one is supported by the developmental effects that were observed for visual stimuli when sequential processing was used (Experiment 3) but not when simultaneous processing was used (Experiment 1). However, it should be noted that schema category responding to simultaneously presented visual stimuli remained prominent even in children. Such a result could be due to the fact that the visual modality increases the weighting of knowledge-based features (see the general modality-specific effects described previously).
Another difference between vision and audition concerns the discrepancy between the perceptual and conceptual levels of responding. In the case of auditory stimuli (Experiment 2), strong and general effects of similarity were observed. The similarities between the target and the schema comparison object and between the target and the taxonomic comparison objects, were important. A different pattern was observed in the case of visual stimuli (Experiment 3) in that similarity effects apply only to the schema comparison objects. These results are open to a number of different explanations. As one explanation, they could be due to the salience of the perceptual information and of the participants' inhibition mechanisms; with highly salient perceptual cues, it may be difficult for participants to consider conceptual or knowledge-based organizations in isolation. Perceptual similarity relations may be strongly weighted in audition even if the task asked for knowledge-based responses. However, the results could also be explained by difficulties in applying conceptual relations. As described previously, these difficulties would be greater for auditory stimuli than for visual stimuli. Thus, perceptual cues would be used to process auditory stimuli and to help participants respond on the basis of a conceptual organization.

Finally, our studies indicate that participants use perceptual cues in conjunction with conceptual knowledge for categorizing. This suggests that the mobilization of a conceptual representational system depends, to a certain extent, on the detection of perceptual information. Such a result is not consistent with what was proposed by Nelson (1983; see also Mandler, 2000). It appears that perceptual analysis mechanisms are important for acquiring conceptual representations (Madole & Oakes, 1999; Quinn & Eimas, 2000) as well as for using or mobilizing these representations during a categorization task. One important finding of this research is that children have difficulties in performing the task in audition at a conceptual level. We propose to explain these difficulties by the auditory processing constraints that favor a comparison on the basis of perceptual cues.

In conclusion, we maintain that an analysis of categorization responding must take into account specific processing constraints (see also Rey & Berger, 2001). In our research, these constraints were related to the nature of the sensory modality. Our results extend the findings of previous work in which the influence of task parameters (e.g., in terms of instruction or learning [Deák & Bauer, 1996]), or of more complex factors (e.g., expertise, domain-based knowledge [Johnson & Mervis, 1997]), has been demonstrated.

References


