The Abstraction of Relevant Features by Children and Adults: the Case of Visual Stimuli

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Abstract

In two experiments, children aged four years and adults were presented with unfamiliar stimuli. They had to segment them into relevant parts. Stimuli presented in a category shared global shape and features, but each occurrence of a potential feature was different. Results of the first experiment show that adults and children found the relevant features despite the differences between occurrences of potential features. Children's selections differed from adults' selections in terms of coherence of the segmentations. In the second experiment, the hypothesis that children used the global shape of the stimuli to find the relevant features was tested. The global shape of stimuli was manipulated in order to assess its role on feature selection. Results demonstrated that the number of incoherences produced by children increased when they could not rely on a global shape for their segmentation. The results are discussed in terms of the relative influence of configural and featural aspects of the stimuli. It is argued that adults rely more on feature identity than children when they segment stimuli into relevant features.

Introduction

Conceptual learning, categorization and the development of expertise are generally described in terms of features. In conceptual development, for example, one might explain the overgeneralization of the word "dog" to all four-legged animals by postulating the feature "four-legged" which is a cue for the category "dog" (Clark, 1983); then, new features like "barks", etc. are added to the concept and distinguish "dogs" from other four-legged animals. However, such an explanation requires that we explain how children know that these features are relevant cues that distinguish dogs from other categories. If one looks at the unfamiliar objects displayed in Figure1 and has to describe them, by pointing to important parts, there are many aspects that could be pointed to, considering either global or more local parts. More generally, if a stimulus can be described by an infinite number of potential features (Murphy & Medin, 1985), how do children and adults come to select specific aspects of stimuli as relevant descriptors?

Two determinants of feature selection have been suggested for visual stimuli: perception (bottom-up perspective), and general knowledge and theories (top-down). In the bottom-up approach, the perceptual system provides the conceptual system with a set of perceptual features that are interpreted as conceptual units in a second step. In theory-based approaches, expectations of the subjects based on their world knowledge influence the features they list about members of a category. For example, Wisniewski and Medin (1994) provide evidence that a set of stimuli were interpreted as having different features depending on subjects' information about their source.

Is there a cognitive function (e.g., perceptual) that provides subjects with a unique set of features usable as relevant descriptors of a category? As many authors have pointed out, the structure of stimuli can be processed at multiple levels (from the overall shape to specific components) and relevant features for categorization could be situated at anyone of these levels. From a developmental point of view, it is unlikely that children know *a priori* all the relevant features for categorization. In this paper, we focus on the role of the structure of categories to which unknown stimuli belong and suggest that construction of relevant features is an active process based on comparisons between the stimuli of a category (Schyns, Goldstone, & Thibaut, 1995; Thibaut, 1991).

In the following experiments, we compare how children and adults segment unfamiliar stimuli presented alone, or as one member of a category. Some developmental psychologists have suggested that, relative to adults, children process stimuli in a more holistic manner. Young children seem to use preferentially holistic properties that are analyzed into components by adults (Kemler, 1989; Smith, 1989). Smith (1989) suggests that young children and adults can isolate stimulus dimensions, but that they differ on their capabilities in selectively focusing on the constituting dimensions when performing object comparisons. Older children and adults emphasize dimensional identity because of their greater skill in focusing on individual stimulus dimensions. Children under six years of age categorize stimuli on the basis of overall similarity (see, however, Ward & Scott, 1987).

In most categorization experiments, subjects are presented with stimuli composed of well defined and clear-cut dimensions, like squares, stars, etc. However, most often, the members of a category are not identical (e.g., different kinds of dogs, or the shape of usual and modern chairs). When a subject encounters a set of unfamiliar stimuli, variations can contribute to the difficulty of abstracting features that potentially defines a category, since the subject has to decide whether parts of different stimuli are exemplars (or not) of the same feature. However, despite these variations, entities that belong to the same category generally share a global shape and the topological relations between features are identical in the stimuli belonging to the category (e.g., different kinds of chairs). When stimuli share an overall shape, variations might contribute to the discovery of relevant features in the stimuli. Imagine which segmentations an extraterrestrial would perform from the picture of a seated person to those he would produce from a moving figure. Arm gestures, for example, indicate that arms are entities independent of the rest of the body. In the first experiment, subjects were presented with a category of unfamiliar stimuli designed in such a way that the potential features that constituted them were never identical in the different stimuli. We compare how children and adults segment a member of the category presented separately or within a category (see Figure 1).

If children are more holistic processors how might they segment stimuli into features? One could argue that their segmentation of a single stimulus will be more holistic, i.e. children will isolate fewer dimensions than adults. If they are presented with a category of stimuli unfamiliar to them in which overall shape is constant, but that display variations at the feature level, how will they segment the stimuli compared to adults? One might suggest the hypothesis that adults will abstract the relevant features despite variations and that children will rely more on the global shape of the stimuli. This could mean that they will isolate fewer features than adults, or that they won't be able to find a coherent segmentation of the category. This would be the case if each stimulus (or subsets of stimuli) is (are) segmented without reference to the other (subsets of) stimuli. To summarize, we compare the features selected as descriptors of a given target stimulus presented separately to the ones selected when the same stimulus is included in a category of unknown stimuli. One hypothesis is that these two contexts should lead to different segmentations and that the way children and adults segment the stimuli will differ.

Experiment 1

A category was designed in which all the stimuli shared the same global shape. We compared the parsing obtained for a target stimulus in two conditions. In the *single condition*, the target stimulus was presented alone. In the *category condition*, it was presented together with all the other stimuli. Children were compared to adults in the 2 conditions.

Methods

Subjects and stimuli. Subjects were 38 children aged 4;0 to 4;11 and 40 undergraduates students from the University of Liège who participated as volunteers. A set of six stimuli was constructed according to the following design. The stimuli were outlines of unknown shapes. A first stimulus was designed in which global (GF) and local (F) target parts were selected *a priori* (see Figure1, global features GF1 to GF3, local features F4 to F7). The other stimuli consisted of distortions of this first form. Each occurrence of a target part of the target stimulus was distorted in the other stimuli. As a consequence, a target part never appeared with an identical shape in two stimuli. The parts were lengthened, or shortened, or broadened, or any combination of these three actions. Each target part was present in each stimulus. All the stimuli had the same global configuration defined by the features GF1, GF2, GF3 ("global shape" in what follows). Local features (F4->F7) were appended to the global feature GF3. All the potential parts (the *expected parts*) (i.e. features mentioned above) were located in the same place on any stimulus (see Figure 1).

Procedure. Adult subjects were randomly assigned to one of the two conditions. They were presented with the category of stimuli (*category condition*) or the target stimulus (*single condition*). In the *category condition*, subjects were told that they would see unfamiliar stimuli from an unknown planet and that the stimuli formed a category. They were asked to circle carefully the main attributes of each stimulus, i.e. the important parts of the stimuli that people could use to recognize or categorize those stimuli. Subjects had to delineate the occurrences of a given part in the stimuli with the same color. The six stimuli were displayed on the same sheet of paper. In the *single condition*, the instructions were adapted for the stimulus presented separately. Subjects were asked to circle the parts of the stimulus that could be important to recognize and categorize it.

The instructions were adapted for children. First, they completed the delineation task with two well-known entities or two well-known categories (chairs and dogs). When the child showed that he/she had understood the instructions, the experimenter presented the child with the unfamiliar category (or stimulus in the *single condition*) and asked him/her to perform the same task that was required for the familiar categories.

There was no time limit. The adults completed the task in 5 to 15 minutes and the children in 25 to 40 minutes. All the subjects were tested individually.

Results and discussion.

Adults' and children's segmentations obtained for the target stimulus were compared in the two conditions. First, a grid composed of the features subjects delineated was built (see Table 1). Subjects selected *expected features* (GF1->GF3, F4->F7), but also other features: combinations of the *expected features*, subparts of them, or combinations of those subparts (e.g., a subpart of G2 and a subpart of G3 could be delineated as one feature).

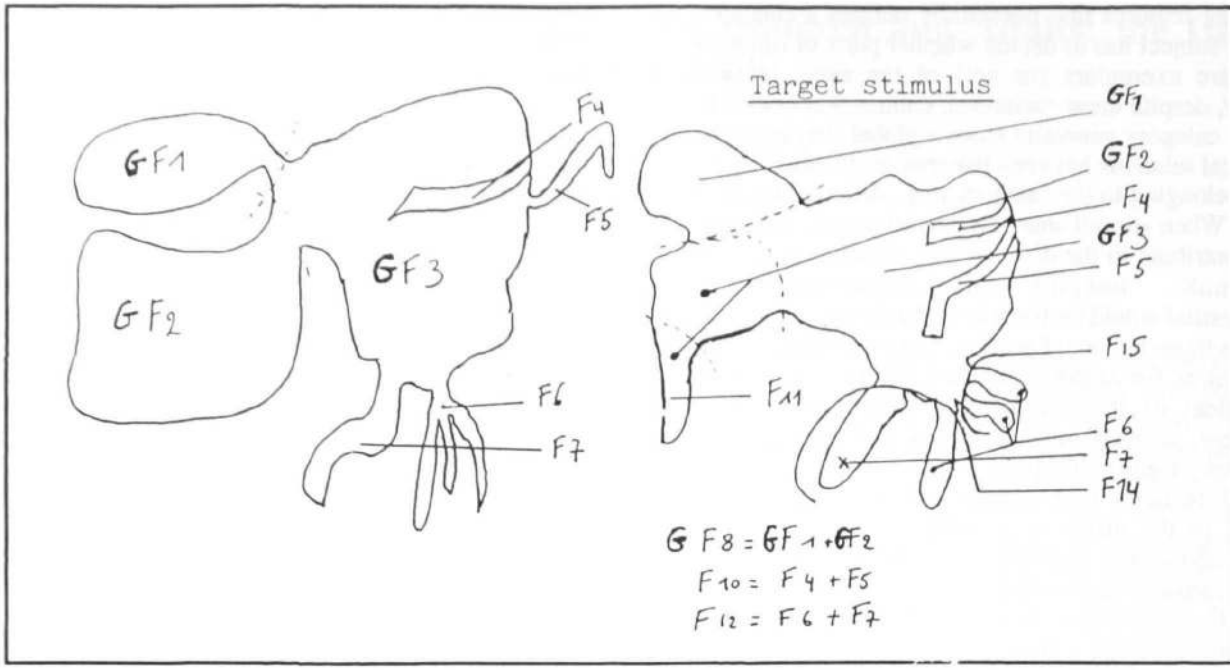

Figure 1: Two stimuli from the category condition including the target stimulus

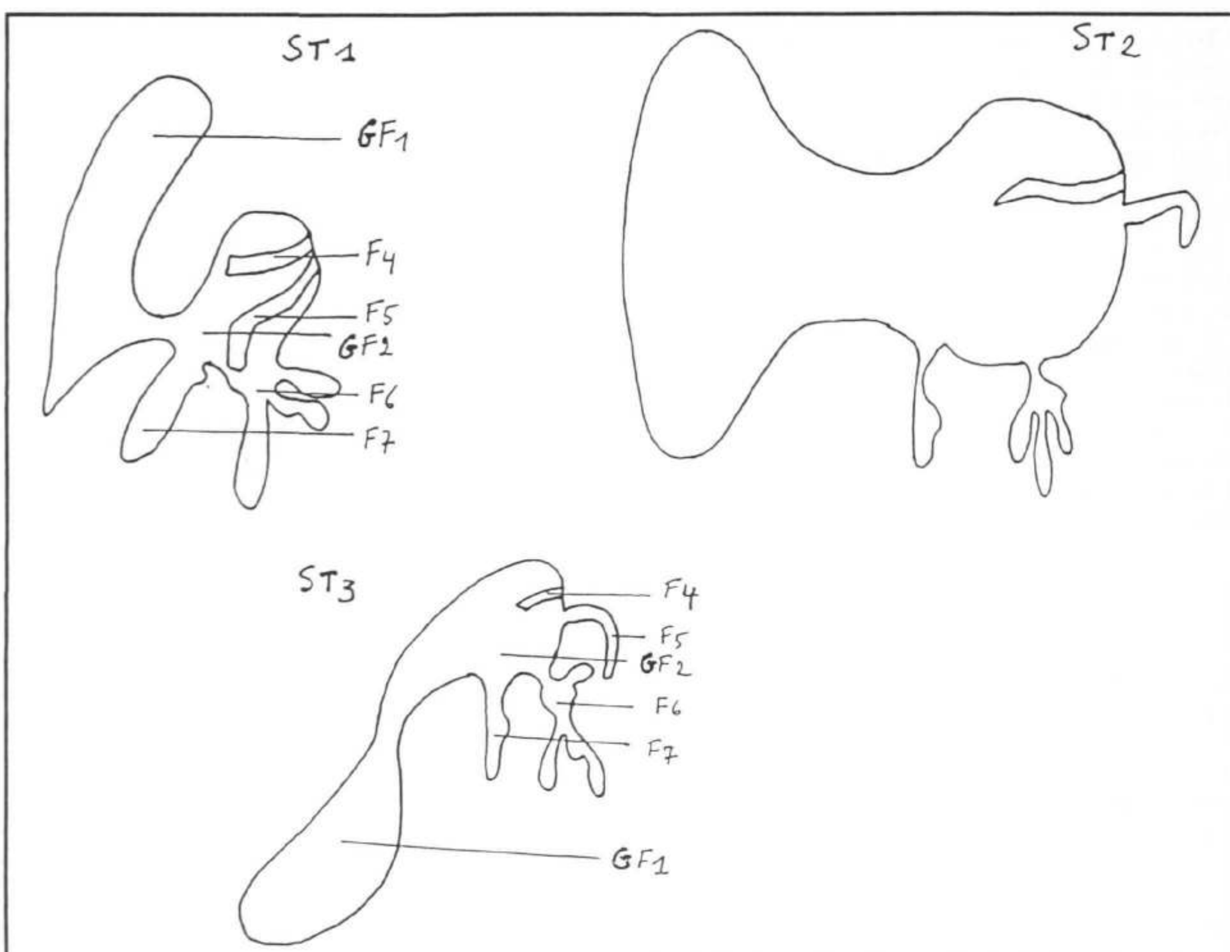

Figure 2: Three stimuli from the second experiment

More than 35 different features were selected, many of them by one subject only. Two independent judges counted the number of times each feature of the grid was selected in each condition by adults and children (Table 1 is restricted to the most frequent attributes). Cases of disagreement between the judges were rare. They concerned infrequent delineations and did not influence results significantly. In order to compare adults and children, the total number of features delineated was computed for each subject. Children and adults were compared in the *single condition* and in the *category condition*. A t-test revealed that children and adults did not differ significantly on the number of selected attributes : for the *single condition*, $t(37) = -1.918$ ($p < .062$); for the *category condition*, $t(35) = -1.642$ ($p < .109$). We also compared the number of *expected features* (GF1->GF3, F4->F7) selected by children and adults in the two conditions. Children and adults significantly differed on the number of attributes in the *category condition* [$t(35) = -3.45$ ($p < .0015$, Adults' mean = 3.2, children's mean = 1.06], but did not differ in the *single condition*, [$t(37) = .842$, $p < .4$].

A further analysis was performed on each feature taken separately. For each feature taken separately, we compared the proportion of subjects who selected it. For feature a given feature*x* (e.g., GF3), H_0 was that the proportion of children who selected it would not differ from the proportion of adults who selected the same feature. In the *single condition*, Fisher Exact Tests revealed that adults selected more often than children the features GF3 and GF8 while children selected more often the feature F11 and F4 (see Figure 1) than adults ($p < .05$). In the *category condition*, Fisher Exact Tests revealed that adults selected more often than children the features GF3 and GF8 while children selected more often the features F11 and F4 (see Figure 1) than adults ($p < .05$), (see Table 1).

TABLE 1 : Number of selections of each feature for the target stimulus in the two experimental conditions for adults and children.

Feature/⇒ Condition⇓	GF1	GF2	GF3	F4	F5	F6	F7	GF8	F9	F10	F11	F12	F13	F14	F15
Single Children	8	1	0	4	5	0	3	1	0	9	12	4	2	6	7
Single Adults	8	3	8	0	1	0	1	10	3	11	4	9	4	3	4
Category Children	4	3	6	1	1	1	1	5	2	6	1	5	2	6	6
Category Adults	8	7	9	9	11	10	10	12	4	4	1	7	1	0	0

Note : "Single" refers to the *single condition* where the target stimulus was presented separately.
"Category" refers to the *category condition*.. F1, ..., Fi, ..., Fn refer to the selected features.

The first analysis showed, in the *category condition*, that adults produced more *expected features* (GF1->GF3, F4->F7 features). This means that they used variations more efficiently than children in order to capture a coherent segmentation of the category. The second analysis of the *category condition* seems to provide evidence that adults are more analytic than children who selected less local features (F4->F7). However, to interpret these differences, first note that F4 and F5, F6 and F7 are local neighboring parts. If children delineated more global parts than adults, these neighboring parts would be unified as larger parts by children than by adults (F4 and F5, F6 and F7 brought together in F10 and F12, respectively). This is not the case as children segmented the feature F12 into F14 and F15 instead of F6 and F7, i.e. they selected other local features. Moreover, adults selected the global feature GF8 (GF1+GF2) more often than children.

Part of the interpretation of the difference between children and adults deals with the fact that the coherence in children's selections of features differed from adults' coherence. Given the structure of the stimuli, a given part of a stimulus always has a corresponding part in each of the other stimuli that takes the same place in the structure of the stimuli (e.g., there is a GF1, a F4 in each stimulus, see materials above). An incoherence was defined as a delineation of a part of a given stimulus having a different structure (e.g., number of subcomponents) and/or location than the corresponding part in the other stimuli (e.g., a subject delineated F5 with a red pen for each stimulus except the target stimulus where he used a green pen). The total number of incoherences in the 20 adults' delineations was 2! However, a number of children did not always follow such a coherence in their segmentation. For example, several children split F12 into F6 and F7 on every stimulus, except one where F12 was split into F14 and F15. Another example of incoherence is related to F7 that was correctly delineated on each stimulus except the target stimulus where F11 took the place of F7. The total number of incoherences in children's delineations was 30.

Children seemed to be misguided by perceptual factors. For example, some children seemed to follow a rule like "what is usually outside should remain outside" when they segmented the target stimulus. As a consequence, some subjects delineated F4 and F5 as different features in each stimulus because F4 is inside the stimuli and F5 outside the stimuli except in the target stimulus where F5 is inside. For that target stimulus, F5 was grouped with F4. Some subjects replaced F5 in the target stimulus by the upper part of F6, i.e., an external part pointing to the outside. Some children used the perceptual cue "verticality versus horizontality": for example, in the target stimulus, F7 and the vertical part of F6 were grouped to form a single feature (F15), and the remaining part of F6 (the two horizontal segments) was selected as another feature (F14). Some children modified the location of a feature in one stimulus: for example, F7 was selected correctly in each stimulus except the target stimulus where F7 was replaced by F11. A possible consequence of these local incoherences was that, sometimes, a feature selected for 5 stimuli had no counterpart in the sixth one (e.g., F7 was selected in each stimulus except the target stimulus).

The analysis of these incoherences supports the idea that children rely on the global shape (configural aspects) of the stimuli to select relevant features. First, incoherences are obtained, for a given stimulus, when the relationship between a local feature and the global shape of that stimulus is different from the equivalent relationship in the other stimuli. This is the case for the target stimulus which was responsible for the majority of incoherences (e.g., a number of children selected the upper part of F6 as an occurrence of F5 in the target stimulus because the "real" F5 is located inside this stimulus). Second, children do not take the position of the local features on the global structure into account in the same as adults. For the target stimulus, some children selected the local F11 which is connected to GF2 (or is a subpart of GF2), for F7 which is connected to GF3. Third, children also select features irrespective of their local structure. For example, in the target stimulus, some children split F6 into its upper part on the one hand, and the other two parts on the other hand, despite the fact that in the other stimuli F6 is composed of 3 subunits.

In short, the location of the features and their local structure (shape, number of components) determine feature selection by adults. The relations between the features selected in one stimulus must be confirmed by the corresponding features in the other stimuli. Children produced more incoherences. Children did not always pay attention to the location and the structure of the features they selected and seemed to rely more on the global, configural aspects of stimuli.

Experiment 2

This experiment tested more precisely the role of the configural aspects of the stimuli (global shape) on segmentation. It was hypothesized that if stimuli do not display a global shape, children will produce more incoherences (see above) in their segmentations than in the preceding experiment. New stimuli were constructed the size and shape of which were more variable than in the preceding experiment.

Method

Subjects and stimuli. Subjects were 14 children aged 4;0-4;11 and 20 undergraduates students from the University of Liège participating as volunteers. A set of six stimuli was constructed (see Figure 2). The features F4, F5, F6, F7 from the preceding experiment were used. Their shape and size were identical to the one they had in the preceding experiment. Their location on the parts to which they were attached remained the same, i.e., F4 was always on the top of F5, and F6 always on the left of F7. Two other features were used, GF1 and GF2. GF1 and GF2 in the present experiment are the equivalent of GF8 and GF3 respectively, in the first experiment. The features F4 to F7 were connected to GF2 in the same way that they were connected to GF3 in the first experiment (see Figures 1 and 2). The shape and size of GF1 and GF2 were more variable than the equivalent features, GF8 and GF3, in the preceding experiment. Compare, for example, the shape and size of F1 for the stimuli St1 and St2 (see Figure 2).

Procedure.

The instructions are the same as in the preceding experiment. There was no cut off. The adults took approximately 10 to 15 minutes to complete the segmentation test, whereas the children completed the task in 30 to 40 min. Subjects were tested individually.

Results.

Two independent judges counted the number of incoherences in adults' and children's segmentations. We compared the number of incoherences produced by adults and children. The 20 adults produced 12 incoherences (mean of .6 incoherence), the children produced 96 (mean of 6.86 incoherences).

As expected, the children produced significantly more incoherences in the present experiment than in the first one (Mann-Whitney, two-tailed, $z = -3.215$, $p < .0013$), (the average number of incoherences is 1.812 in the first experiment, 6.714 in the second experiment). This result can be related to the fact, for adults, that the relevant segmentations were clearer in the present experiment than in the first one. This difference is suggested by the number of different segmentations produced by adults in the two experiments. In the first experiment, there were 19 different segmentations (out of 20). In the second experiment, 7 different segmentations were obtained (out of 20). A Fisher Exact Test indicates that these proportions differ significantly ($p < .001$).

General discussion

The first experiment showed that adults and children found relevant features for the description of a category despite variations displayed by the features across stimuli. However, the results indicated that adults selected more *expected features* than children in the *category condition* but not in the *single condition*. This could mean that for adults, variations at the feature level contributed to reveal the constant parts of the stimuli and their limits. Children selected fewer "areas of variations". This result is consistent with the fact that they rely more on configural aspects of stimuli. It is likely that the abstraction of commonalities despite the presence of variations requires a fine-tuned analysis of the parts of the stimuli. Adults' segmentations also appeared to be more coherent than those of children, in the sense defined above. The fact that children produced more incoherent segmentations in the second experiment than in the first one supports the hypothesis that they rely on the global shape of stimuli. In the*category condition*, the extraction of features requires that subjects used two kinds of similarities: similarity in terms of the internal perceptual structure of features, and similarity in terms of position on the stimulus.

In our experiments, the fact that two features have a similar perceptual structure does not mean that they are identical since the shape of features was varied across stimuli: children and adults do not use the internal structure in the same way. Adults delineate parts that the display the same internal structure (e.g., a potential feature with 3 subparts must display these 3 subparts across stimuli). On the contrary, children seem to emphasize local perceptual cues like (inside vs outside the shape) or (vertical vs horizontal position of a part). As a consequence, the features that they selected did not always display the same internal structure across stimuli. To summarize, children and adults do not value the same kind of similarities: adults value identity at a structural level, while children value identity at a surface perceptual level. At the relational level (i.e., the spatial position of features on the stimuli), children also differ from adults who delineated features which displayed the same position across stimuli. Children attribute more weight to superficial perceptual aspects of a feature than to their position on the stimuli even if perceptual aspects contradict the positional aspects. This means that children do not integrate the relational aspects between features and the perceptual properties of those features into one coherent picture of the stimuli. Other experiments have shown that relational aspects is a source of troubles for children (e.g. relational analogies, see Gentner & Rattermann, 1991).

In the introduction, we mentioned three determinants of feature extraction: perception, theories, and structure of the stimuli belonging to a category. The preceding experiments investigated the relationships between perceptual and category information. We did not manipulate theoretical aspects (in the sense of Murphy & Medin, 1985) in the present experiments. However, preliminary evidence seems to indicate that providing theoretical information (e.g., by suggesting a name for the category) do not change the general picture given by the present results.

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