# Hierarchical Processing of Stimuli by Adults, 5-Year Olds, and Monkeys

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## Introduction

Humans are predominantly visual creatures when it comes to collecting information from the world. A critical part of information-gathering that occurs early on in cognition and sets the stage for all later processing is the perceptual parsing of the visual input, more specifically, the cognitive work of grouping features for object identification. Recent research in developmental psychology suggests that human babies analyze their environment to separate visual scenes into figures and backgrounds, and to separate figures into individual units that correspond to objects (Slater, 2001; Rochat, 2001). Primates' visual perception also seems designed for organizing the world in terms of objects. Early developmental studies of monkey visual perception document that primates (including monkeys and apes) show predispositions toward a selective, highly organized experience of objects (Fantz, 1965).

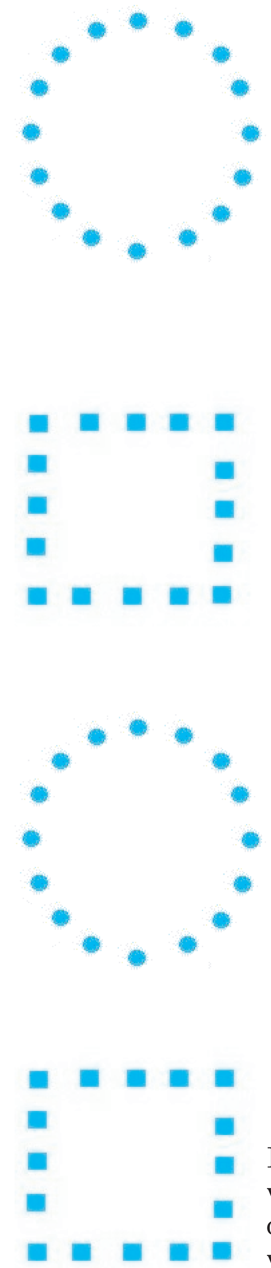
Of particular interest in assessing the perceptual world of primates including humans is how we sift through all the visual cues provided in backgrounds, objects, and patterns within objects in order to identify salient elements. There is solid evidence that human adults process visual stimuli predominately by global and holistic properties. Various researchers have demonstrated a global precedence effect (Navon, 1977, 1981) in which human adults respond more quickly to the global properties (i.e., the shape and overall contour) of figures constructed of smaller stimuli (the local property), and only notice the elements of construction later in the process.

Very young human infants show a global processing bias (Ghim & Eimas, 1998; Quinn, Johnson, Mareschal, Rakison, and Younger, 2000), although in all of these studies, infants also show a sensitivity toward both local elements and global shape. There is evidence that global processing is based on right-hemisphere processing of perceptual events (while local occurs more in the left hemisphere) (Ivry & Robertson, 1998). Logically, because the effect itself seems to occur at early stages of perceptual processing and seems lateralized to different pathways for processing, it seems mediated at a sensory level and probably occurs well before language-related processes are used.

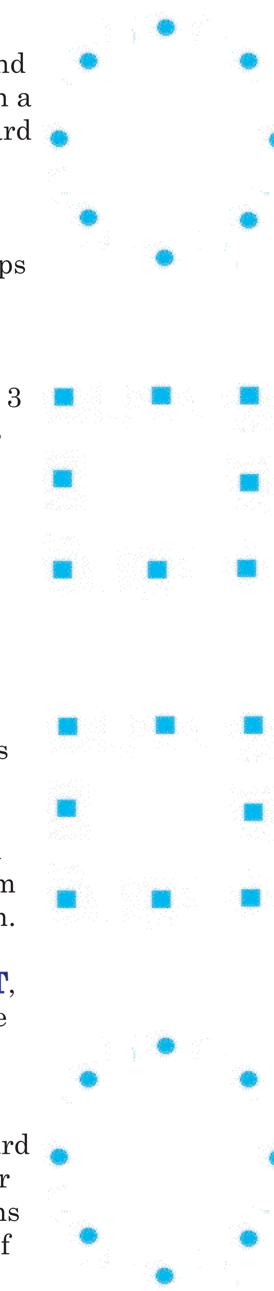
Does the effect mark a predispositon in the human perceptual system for configural-holistic property perception? Or do we share the global biases we show with other primates? This study examines the tendency to discriminate based on global vs. local elements in 5-year old children, adult humans, and adult New World (NW) monkeys to answer this question.

## Method

### Many



### Few



***Adult humans.*** A total of 35 college students, divided so that approximately 50% were in a "few elements" condition (n=17) and 50% were in a "many elements" condition (n=18), participated in a categorical task in PsyScope to which they made explicit keyboard responses to circles made of circles and to squares made of squares.

***Children.*** A total of 12 5-year old children, split into two groups (n=6) for "few" and "many" conditions, participated in the same experiment as the adults.

***Monkeys.*** A total of 8 adult cotton-top tamarins, 5 females and 3 males, were divided into two groups (n=4) according to stimulus condition, and participated in a go/no go discrimination task involving the same stimuli as were shown to humans, only presented on laminated cards to which they responded.

Stimuli

The stimuli in the training phase were circles made out of small blue circle elements and squares made out of small blue square elements. Two different densities of the smaller elements were used to create the "*few*" and "*many*" condition. The circle elements were 4 mm in diameter, and the square elements, 4 mm X 4 mm. In the *few* condition, there were 8 elements which made up the global shape. In the *many* condition, there were 16 elements used to make up the global shape. The global circle shapes were 55 mm in diameter, while the global square shapes were 41 mm X 41 mm.

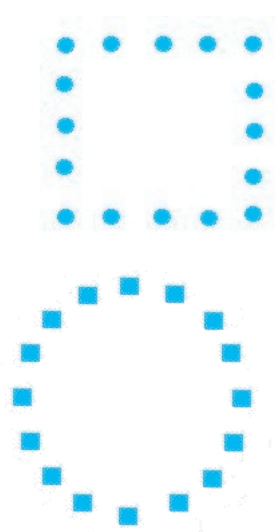
Stimuli in the *few* elements condition are presented to the **RIGHT**, while stimuli in the *many* elements condition are presented to the **LEFT**.

Training

For ***humans***, the task was to learn to hit one letter on the keyboard when they saw a circle shape made of circles, and a different letter on the keyboard when they saw a square made of squares. Humans were subjected to 20-trial blocks containing single presentations of the circles and squares, with each trial starting with a fixation point asterisk for 300 ms, followed by the stimulus presented in one of 4 quadrants on the screen, or centered. Once humans responded correctly in 16 out of 20 trials in one block, they were advanced to the test phase.

For ***monkeys***, the task was to respond on the card with a circle made of circles. Each trial consisted of presenting monkeys with 2 cards (a circle and a square) in two fixed locations on a cart. They were allowed 60 seconds to respond, and were rewarded with sweetened cereal for selecting the circle made of circles. Each session consisted of 16 trials, and subjects were advanced to a test phase when they had acquired 80% correct within 1 session of training.

### Conflict



### Conflict

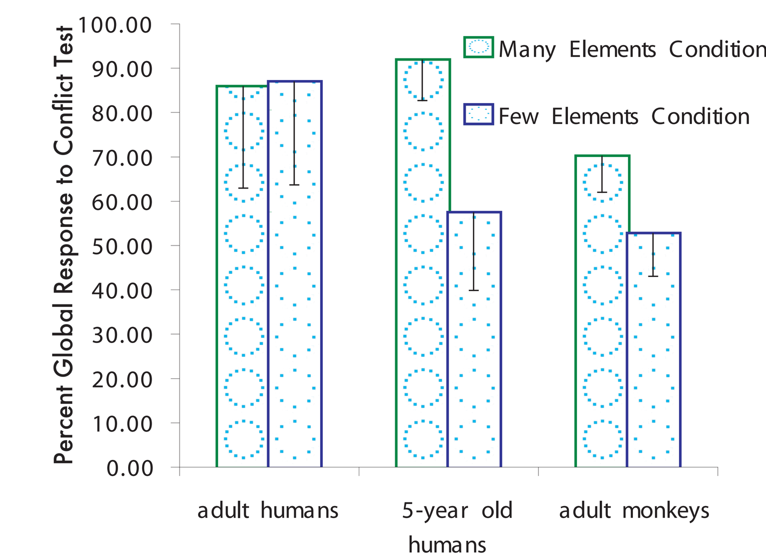
Test

***Humans*** were presented infrequently with new combinations of elements and global shapes, and their responding did not generate any feedback, whereas before a correct response revealed a ☺ and an incorrect response generated a ☹ in training. The main stimuli of interest were circles made of square elements, and squares made of circle elements, for these put the global shape (circle/square) and the local elements (squares/circles) in direct conflict with each other.

***Monkeys*** were presented infrequently pairs of novel cards with the same conflicting cues, and they were rewarded for whichever card they selected. In the Conflict condition graphed here, a global circle (S+) was presented made of square elements (S-), paired with a global square (S-) made of circle elements (S+).

For members of both species, categorizing the circle shape indicated a bias toward global processing, while responding to the circle elements (despite the square global shape) indicated a local bias.

## Results




A fixed model ANOVA compared ***adult humans*** and ***children*** in each of the 2 groups defined by condition (FEW/MANY) to examine the percent of responses any group made globally (e.g., responded with the circle made of circles key toward the circle made of squares). Levene's Test of Equality of Error Variances was used to establish that the four groups, while using different numbers of subjects, had similarly homogeneous variances ($F(3, 43) = 0.805$, $p=0.498$).

The ANOVA revealed a significant main effect of AGE ($F(1, 43) = 4.12$, $p = 0.05$), a significant main effect of CONDITION (many/few) ($F(1, 43) = 7.40$, $p=0.009$) and a significant interaction of AGE X CONDITION ($F(1, 43) = 8.28$, $p = 0.006$).

Specifically, 5-year old ***children*** showed a significant difference in their percent global response ($t(10) = -4.93$, $p = 0.001$), with those children in the MANY condition generating more global responses (mean = 91.67%) significantly more often than those children in the FEW condition (mean = 51.85%). Children made a global response to the circle shape when presented with the circle made of square elements at levels higher than chance if they were in the MANY condition ($t(5) = 11.18$, $p < 0.001$), but not if they were in the FEW condition ($t(5) = 0.26$, $p = .81$).

In contrast, ***adults*** showed no significant differences in their percent global response if they were in the FEW condition (mean = 86.76%) as compared to those in the MANY condition (mean = 85.65%) ($t(33) = 0.143$, $p = 0.89$). One-sample t-tests against a hypothetical mean of chance level, or 50%, indicated that adults selected the global response (circle shape) when presented with the circle made of square elements at levels significantly higher than chance when in the FEW condition ($t(16) = 6.53$, $p < 0.001$) and when in the MANY condition ($t(17) = 6.62$, $p < 0.001$).

Nonparametric tests comparing ***monkeys*** (n=4 per group) in the MANY and FEW conditions revealed a significant difference in global response (or selecting the circle made of square elements as the "go" response, as compared to the square made of circle elements) (Wilcoxon rank sum test $W = 11$, $p = 0.037$). Specifically, those monkey subjects in the MANY condition made a global response by selecting the circle shape over the circle local elements at a mean rate of 70% of the test occurrences, as compared to those in the FEW condition (mean = 52.50%). One-sample t-tests against a hypothetical mean of chance level responding, or 50%, indicated that global choice occurred at rates significantly higher than chance in the MANY condition ($t(3) = 4.89$, $p = 0.02$) but not in the FEW condition ($t(3) = 0.52$, $p = 0.64$).

***Monkey*** subjects responded in ways similar to 5-year old ***children*** in that they were biased to respond globally in the MANY condition, but not in the FEW condition. ***Adult humans*** were biased toward the global response in both MANY and FEW conditions.

## Discussion

The presence of a global bias to the dense display (MANY condition) in all 3 subject groups (***children, adult humans, and monkeys***) shows that all 3 groups lead with attention toward the global shape in conditions in which the global shape is well-defined by the elements.

In contrast, the FEW condition, marked by a less dense formation of the global shapes circle and square by fewer local elements, causes the global shape to be less predominant in 2 of the 3 subject groups, in ***5-year old children and in adult NW monkeys***. In fact, both children and monkeys must have processed the local elements and global shape with near-equivalence when they were presented in a less dense display, because they split their judgment of the "correct" stimulus between those with circle shape (independent of what they were made of) and those made of circle elements (independent of the shape the elements defined) about equally often. They did remember the original discrimination, for in all cases, they continued to respond at levels significantly higher than chance to the original stimuli (circles made of circles and squares made of squares) during testing. But when viewing a stimulus that has a mixture of positive and negative cues across global shape and local elements, children and monkeys show through their response that they attended more equally to both global and local cues if the global shape was less pronounced, but more globally if the global shape was more pronounced.

What is surprising is the contrast between children and adult monkeys who both show the effect that density has on their attention toward global and local detail and adult humans who were biased toward discriminations in global shape independent of the density of elements. The results suggest:

> Humans learn to apply a global bias to stimuli regardless of density of elements, and this shift occurs developmentally and may be a result of extended training on grouping by shape.
> Younger humans show a global bias naturally to dense displays, but not to displays in which the elements define weakly the overall shape.
> Monkeys also show a global bias to dense displays, but respond to indicate attention to both local and global elements to stimuli with weak global definition.

Because NW monkeys and humans are not close relatives within the primate order, the results suggest that a global bias controlled by display density and thus overall definition exists in primates generally as an early filter for defining objects. The fact that adult humans attend similarly to the stimuli indicates that a global "shape" discrimination bias unmoved by density display is likely to occur ontogenetically in humans as a result of extended training with categorical judgments and labels.

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