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Processing of contour closure by baboons (*Papio papio*)

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Abstract

This study investigated the Gestalt law of closure in baboons. Using a computer-controlled self-testing procedure, we trained baboons to discriminate open *vs* closed shapes presented on a touch screen with a two-alternative forced choice procedure. One first group of 10 baboons (OPEN+ group) was trained with the open shapes serving as the positive stimulus (S+). Another group of 9 baboons (CLOSE+) was trained with the closed shape serving as S+. The OPEN+ group obtained higher discrimination performance than the CLOSE+ group (Exp 1), but its scores declined when new line segments were added to the stimuli (Exp 2) and after smoothing the end-points of the open shapes (Exp 3). The CLOSE+ group was less affected by the above manipulations of local stimulus dimension, but its performance was disrupted when the collinearity end points was reduced (Exp 3). Use of a visual search task revealed that the search for an open shape among closed distractors was less attention demanding in baboons than the search for a closed shape among open ones (Exp 4). A control experiment (Exp 5) showed that this latter effect is not reducible to a feature-positive discrimination effect. It is concluded that (1) end lines rather than closeness per se are perceptual primitives for the open *vs* closed discrimination in baboons, and (2) that the relative emphasis on local or configural cues when processing contour closure depends on experiential factors in baboons, and is thus subject to inter-individual variations.

Processing of contour closure by baboons (*Papio papio*)

The Gestalt theory is a powerful framework for conceptualizing how perceptual organization occurs. Though developed at the beginning of the 20th century, that theory remains central for contemporary investigators of perception in human adults (Strother & Kubovy, 2006), children (Quinn, Bhatt & Hayden, 2008), but animals also (see Fagot, Barbet & Parron, in press for a review). Founding Gestalt psychologists have attempted to explain how elements of visual displays are grouped to form larger perceptual units. Their main idea was that the perceptual organization reflects the application of several grouping principles (referred to as the Gestalt laws) based for instance on the common fate, good continuation, proximity, and similarity of the stimulus features to be grouped (e.g., Helson, 1933). They further maintained that perceptual grouping is a rigid, pre-constructed process, imposed by the activity of the nervous system (Kanizsa, 1980; Kohler, 1929).

Developmental psychologists have tested the hypothesis of a pre-constructed perceptual organization in human infants. They found that perceptual organization is not a monolithic phenomenon, and have further shown that the Gestalt principles are not all governed by the same underlying mechanisms (see Quinn & Bhatt, 2009 for a review). For example, the principles of good continuation (Quinn & Bhatt, 2005; Quinn, Brown, & Streppa, 1997), lightness similarity (Quinn, Burke, & Rush,1993) and uniform connectedness (Hayden, Bhatt, & Quinn, 2006) have all been found to be functional by 3 months of age, but the principle of form similarity only becomes functional at 6–7 months of age (Quinn, Bhatt, Brush, Grimes, & Sharpnack, 2002). There is also now good evidence that perceptual organization may arise from top–down knowledge of particular objects and object kinds (Needham, 2001; Needham, Dueker, & Lockhead, 2005).

The human and monkey visual systems share many functional properties (e.g., in terms of visual acuity or sensitivity to contrasts: e.g., de Valois & de Valois, 1971; Fobes & King, 1982) as well as neurophysiological processes (Merigan & Maunsell, 1993). As a direct consequence of these similarities, comparative studies involving monkeys may efficiently test the hypothesis that the perceptual organization is “pre-constructed” phenomenon. If the human perceptual organization is predetermined by the functional properties of the nervous system, the perceptual organizations of monkeys and humans should be highly similar. This issue has recently generated a great deal of interest in comparative cognition. Many of these studies use the global/local paradigm of Navon (1977).

The Gestalt theory claims that “the whole is different from the sum of its parts”. To assess that idea, Navon (1977) investigated if the whole of visual configurations are perceived before their constitutive parts. To do so, he used hierarchical stimuli structured in a clear two-level hierarchy containing essentially the same information, the global and local levels. They consisted of large letters of many appropriately positioned small letters. Navon found that response times (RT) were faster to global than to local letters, and coined that effect “global precedence”. Comparative studies of human and nonhuman primates using that global–local paradigm have shown that, in contrast to humans, several primate species including capuchins (De Lillo, Spinozzi, Truppa, & Naylor, 2005; Spinozzi, De Lillo, & Truppa, 2003; Spinozzi, De Lillo, & Salvi, 2006), baboons (Deruelle & Fagot, 1998; Fagot & Deruelle, 1997), macaques (Hopkins & Washburn, 2002) and chimpanzees (Fagot & Tomonaga, 1999) reliably demonstrate a local rather than a global precedence. One hypothesis to account for that effect is that proximity grouping is not as efficient in monkeys or apes as it is in humans (Fagot, Barbet & Parron, *in press*). In support of this hypothesis, increasing the density of the compound stimuli affects negatively the processing of the global shapes (De Lillo et al., 2005) or reduces the local advantage (Deruelle & Fagot, 1998; Fagot & Deruelle, 1997; Fagot &

Tomonaga, 1999; Spinozzi et al., 2003), but in that case, animals showed no reliable advantages for either stimulus level (but see Neiworth, Gleichman, Olinick, & Lamp, 2006). Comparative investigations therefore suggest human / nonhuman primate differences in global precedence and a reduced proficiency for proximity grouping. A reduced sensitivity to grouping cues has also been reported in other nonhuman species, such as rats (Kurylo, Van Nest, & Knepper, 1997; Kurylo, 2008) and Australian sea lions (Burke, Everingham, Rogers, Hinton, & Hall-Aspland, 2001) in tasks featuring bistable arrays of dots.

Proximity is only one of several grouping cues that animals may use for object recognition. Unfortunately, very few studies have investigated these alternative cues in nonhuman primates. Spinozzi, De Lillo, Truppa, & Castorina (2009) study aimed to evaluate the relative weight given to proximity, similarity by shape, and orientation as perceptual grouping cues in humans and capuchin monkeys. They compared performance of the two species in a figure-ground segregation task requiring the participants to identify the form of a multi-element pattern displayed on a background of other elements. Capuchin monkeys were able to identify the shape of compound patterns, but differences emerged between humans and capuchins in their use of shape similarity. From the authors, these results suggest species differences in the weighting assigned to different grouping cues.

In that context, the current research focused on the contribution of one grouping cue which has received very little attention so far in the animal literature, namely closure. Early Gestalt psychologists have emphasized the role of closure in perceptual organization. They claimed that "If a line forms a closed, or almost closed, figure, we no longer merely see a line on a homogeneous background, but a surface figure bounded by the line" (Koffka, 1935, p. 150). Since that initial theorizing, the contribution of closure to perception was confirmed by numerous studies involving human adults (e.g., Elder & Zucker, 1993, 1994, 1998; Kimchi, 2000; Kovacs & Julesz, 1993; Marino & Scholl, 2005; Saarinen & Levi, 1999). It was for instance reported that grouping by closure occurs early and rapidly during perception (Kimchi, 2000), that shape discrimination is more precise for closed contours than for open ones (Saarinen & Levi, 1999), and that the search for a concave target among convex distractors is efficient for closed stimuli but inefficient for open ones (Elder & Zucker, 1993).

Investigations of the contribution of closure in the animal literature are scarcer. Spinozzi, De Lillo, & Castelli (2004) have compared performance of humans and capuchin monkeys in an embedded figure task. They found that humans identified the different stimulus parts of a sample complex pattern easier when the parts can be assembled on the basis of grouping principles, such as closure and good continuation. By contrast, capuchins did not rely on these grouping principles in the task, but showed instead a remarkable bias to identify the parts as a set of disconnected elements. From that study, however, it would be difficult to conclude that the monkeys do not process closure and good continuation as recognition cues, as that processing might have been masked by the demand of the task in terms of proximity grouping (for which they have difficulties). In fact, there are reasons to suspect that closure and good continuations are important cues for monkeys. In natural setting, the processing of these two cues appears highly adaptive. Closure and good continuation might for instance contribute to object recognition despite partial occlusion. Nonhuman primate species can complete occluded contours (e.g., Fagot, Barbet, Parron, & Deruelle, 2006; Sato, Kanazawa, & Fujita, 1997) or perceive illusory contours from disconnected elements (e.g., Fujita 2006).

The current research aims to assess the contribution of closure and good continuation as cues for object recognition in monkeys. In four consecutive experiments, we trained and tested baboons to discriminate stimuli consisting in a single continuous line that was either open or closed. By using these stimuli, it was possible to investigate closure processing in experimental conditions that both minimized and equated the need for proximity grouping.

Experiment 1

Experiment 1 firstly aimed to test if baboons can discriminate open from closed shapes presented in the context of a two-alternative forced choice procedure (2-AFC). Its second goal was to test post-learning transfer to new open or closed shapes, to assess a possible use of the discrimination procedure in new contexts.

Method

Animals and housing. The study involved 19 computer-trained Guinea baboons (*Papio papio*), including 11 males (mean age = 12.54, *SD* = 11) and 8 females (mean age = 9.7; *SD* = 7.2). A first set of 6 baboons (i.e., B03, B05, B06, B07, B11 and B15) had a very long experimental history involving either a joystick (e.g., Fagot & Deruelle, 1997; Fagot & Cook, 2006) or a touch screen for responding (e.g., Fagot & Parron, 2010). These animals live in the CNRS Primate Facility in Marseille where they are maintained in small sized groups of either two (for two groups) or three baboons. These baboons are kept in large indoor enclosures (18 m²) connected to outdoor (18 m²) compounds. The other thirteen baboons belong to a large group of 26 Guinea baboons installed inside a 670 m² enclosure connected to a housing area. This group lives within the CNRS Primate Center in Rousset-sur-Arc (France). These latter baboons include an almost balanced number of six males (Articho, Barnabé, Bobo, Cauet, Cloclo and Vivien) and seven females (Angèle, Arielle, Athmosphère, Kali, Michelle, Vanina and Violette). They have only approximately three months of exposure with computer experiments (Fagot & Bonté, 2010).

All baboons are marked by two biocompatible 1.2 X 0.2 cm radio frequency identification (RFID) microchips, one implanted in each forearm. Monkeys are not food deprived. They receive their daily ratio of monkey chows, vegetables and fruits once a day in the housing area, often at 5 pm but at 9 am during the week-ends. Water is continuously available by water dispensers installed in the enclosure and housing quarters. All monkeys were familiar with the automatic learning device for monkeys (ALDM, see Fagot & Bonté, 2010, Fagot & Palleressompoule, 2009; Fagot & Parron, 2010) used for testing. This device is described below.

Apparatus – ALDM test system. The experiment employed ALDM test systems which are new technical devices allowing the test of the baboons on a voluntary basis, while maintained in a social group, and on a 24 hour schedule. Each ALDM test system consists in a freely accessible test chamber (.7 X .7 X .8 m). The innermost front side of the test cage is fitted with a 7 X 7 cm view port and two 8 X 5 cm hand ports. The view port allows vision of a 19 inches 1024 X 768 pixel definition liquid crystal display (LCD) touch monitor installed at eye level 25 cm from the view port. Introducing one hand through one hand port permits actions on the touch screen. Two antennas are fixed around each hand port. They automatically read the identity (ID) number of each participant when it introduced one of its forearms through one of the two arm ports. Numeric identification signals from the forearm tags serve as input for the computers to trigger the presentation of the stimulus, and to assign behavioral measures (stimulus choices and RTs) to each participant. The equipment is controlled by a test program developed by the first author using Eprime language (V 1.2, Psychology Software Tools, Pittsburg, US). The main feature of this program is to allow independent tests regimen for each baboon, irrespective of the order in which each baboon spontaneously enter the test booth and, for the larger group of baboons, which ALDM test system it is using. Grains of dry wheat are used as reward. They are delivered inside the ALDM monkey area by a homemade food dispenser fixed atop the system.

A total of 13 ALDM systems were employed for the current research. Three of them were installed within the outdoor enclosure where the three small-sized groups live (Marseilles' groups). The other ten were used by the larger group (Rousset's group). The 10 latter test systems are installed inside two 32 m2 test rooms, five in each test room, and are freely accessible from the enclosure by way of opening made in the wire mesh of the enclosure. More technical details regarding the equipments and their implementation are provided in Fagot & Paleressompoulle (2009) and Fagot & Bonté (2010).

Stimuli. Figure 1 shows examples of the stimuli. They consisted in random shapes made of a 6 pixel thick yellow line presented on a black computer screen. As illustrated in Figure 1 (panel a), there were two kinds of shapes: polygonal shapes and curvilinear. Each shape was constructed in both an opened and a closed version. The open shape contained a single 30 pixels wide gap randomly located on the contour of the stimulus. Gaps in these stimuli were neither located in vertex of polygonal shapes nor at points of high degree of change in the curvilinear shapes, because these features are particularly important for object perception (Attneave, 1954). The closed shape contained no such gaps. All stimuli were 15.3 X 15.3 degrees of visual angle (200 x 200 pixels). A total of 120 (60 polygonal and 60 curvilinear) shapes were used for the learning and testing phases of Experiment1.

Insert Figure 1 about here

General procedure. A 2AFC procedure was used. A trial started when a baboon introduced its left or right forearm through one of the two arm ports. That procedure identified the participant, and loaded the parameters of the trials assigned to it. Two stimuli appeared on the touch screen after the identification period, one on the left of the screen and one on its right, separated by 450 pixels. The two stimuli used in each trial had an identical overall shape, but one of them contained a gap randomly located on its contour, and was therefore an open stimulus. The other one was closed. One of the stimuli was designated as the positive (S+) stimulus, and the other was the negative (S-) stimulus. The left-right location of S+ and S- were counterbalanced. The baboon had to select S+ by touching the screen. Correct responses delivered a food reward. Incorrect responses were followed by a 3-s timeout during which the screen turned green. All trials were followed by a 3-s inter trial interval (ITI) during which the screen remained black. The subject could proceed to the next trial after that ITI period.

Training and test procedure**.** Initial training was required to have the baboons learning the discrimination problem. Two groups of subjects were distinguished during the training period and consecutive test periods. S+ was the closed shape for the first group which comprised 9 baboons (Angele, Articho, Atmosphere, Cloclo, Vanina, Bobo, B03, B05 and B15). This group will hereafter be referred to as the CLOSE+ group. The other group (OPEN +) was tested with the open shape serving as S+. It comprised a total of 10 baboons (Arielle, Barnabe, Cauet, Kali, Michelle, Violette, Vivien, B06, B07 and B11). To control for prior experience with computerized tasks, half of the baboons from the Marseilles' group, which were highly familiar with computerized testing, were assigned to the OPEN+. The other half was assigned to the CLOSE+ group.

In the first training phase, the baboons were required to learn the open *vs* closed discrimination when the stimuli comprised a large gap of 60 pixels in the open figure. Training sessions contained 120 randomly ordered training trials using 80 different stimuli involving both polygons and curvilinear shapes. The gap of the open shape was reduced to 30 pixels in training phase 2. Training sessions at this stage contained 120 trials involving the same stimuli as in the first training phase, but with a reduced gap. Training sessions were repeated until individual performance reached 85% correct or more in three consecutive sessions of each phase.

The testing consisted of 512 trials per baboon, organized into 4 sessions of 128 randomly ordered trials. Each test session contained 96 baseline trials involving the same stimuli as during training, and 32 probe trials with 32 new S+ stimuli and their corresponding S- version, with their left/right position on the screen counterbalanced. Baseline trials were differentially reinforced. Probe trials were randomly reinforced at a rate (85%) corresponding to the minimal reinforcement rate achieved at the end of training.

Results

Training. The baboons from the Marseilles' group required less training sessions (mean=7.67) in phase 1 than the baboons from Rousset (mean=14.69, $t(17)=2.4$, $p<.03$), but this difference disappeared in the second training phase, $t(17)=1.14$, $p>.05$. For the OPEN+ group, reaching the training criterion required 10.9 sessions on average (*SD*=7.05) in training phase 1 and 7.5 sessions (*SD*=9.01) in training phase 2. For the CLOSE+ group, training respectively required 14.22 (*SD*=6.12) and 26.11 (*SD*=22.98) sessions in training phases 1 and 2. A Test group (OPEN+, CLOSE+) by Training phase (phase 1, phase 2) analysis of variance (ANOVA) computed on the number of training sessions to criterion revealed a significant effect of Test group, $F(1,17)=4.88$, $p<.04$, and a Test group by Training phase interaction, *F*(1,17)=5.43, *p*<.03. Post-hoc *HSD* Tukey tests (*p*<.05) showed that reducing the gap size in phase 2 affected performance of the CLOSE+ group (mean phase 1=14.22 sessions, phase 2=26.11) but had no detrimental effect for the individuals of the OPEN+ group (phase 1=10.9 sessions, phase 2=7.5).

Testing. Trials with RTs greater than 4-s were discarded for statistical analyses because they may either reflect inattention to the task, or a participant change within the ALDM test system during the trial. The baboons demonstrated an excellent accuracy during testing (mean=89.97% correct, *SD*=3%). There was no reliable difference between the performance achieved in baseline (mean correct=90.02%, *SD* = 2.99%) and probe trials (mean correct=89.81%, *SD* = 3.02%; paired t-test, *t*(18)=0.19, *p*=0.85). High performance in the probe trials demonstrates positive a transfer to new stimuli.

Statistical analyses were pursued with an analysis of variance (ANOVA) on scores. It used the baboon's Troop (Marseille, Rousset) and Test group (OPEN+, CLOSE+) as two between subject factors, and the Sessions (1, 2, 3, 4) and Shape (polygonal, curvilinear) as two within subject factors. There was no reliable main effects (all *ps* > .05) but a reliable Session X Test group two-ways interaction, *F(*3, 51)=3.45, *p*<.024. Post hoc analyses (Tukey *HSD* tests, *p*<.05) indicated a higher performance for OPEN+ test group than for the CLOSE+ group, which was limited to the first test session (OPEN+ group: mean session 1 = 94.21%, *SD*=8.68; CLOSE + group: mean session 1= 86.29%, *SD*=8.65%). There was also a reliable Shape X Test group interaction, *F*(1, 17)=4.96, *p*<.04. The OPEN+ group obtained better performance with the curvilinear shapes (mean=92.9% correct, *SD*=7.8%) than the CLOSE+ group (mean=87.4%, *SD*=9.5%; Tukey *HSD*, *p*<.05). There were no reliable differences between the test groups when the polygonal shapes were considered (OPEN+: mean=89.5%;

SD=8.8%; CLOSE+: mean =88.9%; *SD*=7.4%). None of the other interactions reached significance (all *ps* < .05).

Discussion

Experiment 1 suggests three main conclusions. First, baboons could learn the open *vs* close shape discrimination problem, after an average of 7048 trials, and could maintain a performance over 85% of correct responses on average in probe trials using new stimuli. This transfer of performance in probe trials demonstrates that the discrimination procedures acquired during the training period were not tied to the specific stimuli used in training. Second, although the baboons from Marseille learned the task faster than their counterparts, there were no reliable performance differences between the two groups during the test phase. This finding suggests that the two groups had identical strategies once learning was achieved. Third, the OPEN+ group outperformed the CLOSE+ group in test session 1, suggesting group differences in their processing of the task.

One important characteristic of the open shapes is that they contain line ends that are basic features in shape perception (Julesz, 1984). It can therefore be proposed that the baboons from the OPEN+ group paid particular attention to the end points of the lines delimitating the stimulus gap, and used a local mode of processing to that aim. Because polygonal stimuli contain acute vertices perceptually similar to the segment end points, this hypothesis explains the reduced performance of the CLOSE+ group with these stimuli. By contrast, baboons from the CLOSE+ group would be more sensitive to closure as a global cue, rather than the mere presence or absence of the endpoint processed as local features. Support of this latter hypothesis derives from the second training phase using a reduced gap size in comparison to the first training phase. Baboons from the CLOSE+ group required more additional training sessions in phase two than the OPEN+ group. As the number of end points was independent of gap size, this difference suggests that the baboons did not only attend the local properties of the end points to solve the open/closed discrimination problem, but also process some aspects of their configuration. Comparison of the performance in the two training phases supports that conclusion. We found that a reduced gap size increased the difficulty of the task for the CLOSE+ group. This phenomenon, which already been reported in the human literature (Elder & Zucker, 1993, 1994; Gillam, 1975; Hadad & Kimchi, 2006, 2008; Mori, 1997; Treisman & Souther, 1985), suggests that closeness was processed in our task as if it was continuous rather than a binary dimension.

Experiment 2

In the previous experiment, end points were present in open stimuli but absent from the closed stimuli. In Experiment 2, short line segments with end points were added to all stimuli to now have end points in both the closed and open stimuli. We hypothesized that if baboons based their discrimination on the detection of line ends, then their performance should deteriorate when these line segments were added, because both S+ and S- now contain end points. In addition, assuming that the baboons from the OPEN+ group attended in particular the end points of the lines delimitating the stimulus gap, adding of new endpoints in the displays should be particularly disruptive for that group.

Method

Apparatus and participants. The ALDM test systems were the same as in Experiment 1.

Stimuli. The stimuli used in probe trials are illustrated in Figure 1 (panel b). They were 64 new polygons or curvilinear shapes. Half of them were new forms constructed from the same principle as in Experiment 1. The second half were new open or closed shape to which two 30 to 40 pixels long line segments have been added somewhere on their contour. These segments were presented either inside the shapes for 16 of these latter stimuli, and outside it for the remaining 16. The other aspects of the stimuli, for instance regarding their color or visual size, were identical to Experiment 1.

Test procedure. The task was in its general principle the same as in Experiment 1. Baboons from the OPEN+ and CLOSE+ groups were both presented with 4 test sessions of 256 trials each. Each test session comprised 192 baseline trials involving stimuli used during training and testing of Experiment 1. They also contained 64 probe trials involving the presentation of 32 new stimuli with no end line added (no-added line condition), 16 new stimuli with added lines inside the stimulus (added line IN condition), and 16 other new stimuli with added end lines on the external contour of the stimulus (added line Out). Baseline trials were differentially reinforced. All probe trials using the new stimuli were randomly reinforced at an 85% rate, just as in Experiment 1.

Results

Baboons obtained a high performance in probe trials (mean correct = 85.62%, *SD* = 5.5%). Performance was however higher in baseline trials (mean correct = 92.21%, *SD* = 3.58%) than in probe trials (paired t-test, $t(18)=5.33$, $p<.001$).

We firstly compared performance obtained in the no-added line and added-line probe trials, without considering the distinction between the IN and OUT line segments. As there were no reliable differences in Experiment 1 between the baboons from Marseille and Rousset, this analysis and the next ones no more distinguished these two groups. The ANOVA considering the Test group (CLOSE+ and OPEN+) as the only between subject factor, and Test condition (no-added line, added line), the Session (n=4) and the Shapes (polygon or curvilinear) as the within subject factor, revealed a main effect of the test condition, *F*(1, 17)=94.36, *p*<.001. Baboons performed better in the no-added line (mean = 93.38% correct, *SD*=7.99%) than in the added line condition (mean = 77.78%, *SD*=13.06%). The Test group x Test condition interaction and the three-way Test group X Test condition X Shapes interaction were significant (respectively : *F*(1,17)=8.164, *p*<.011), *F*(1,17)=4.81, *p*<.04). As shown in Figure 2, adding lines segments to the stimuli affected performance of the OPEN+ group for both polygonal and curvilinear shapes. For the CLOSE+ group, this effect was only observed for the polygonal shapes (Tukey *HSD*, *p*<.05).

Insert Figure 2 about here

Another ANOVA tested the difference between the added line IN and OUT conditions. This ANOVA used the group (CLOSE+ and OPEN+) as between subject factor, and the Session (n=4), Shapes (polygonal, curvilinear) and Location of the added lines (IN, OUT) as within subject factors. It revealed two reliable interactions. The first one was a two-way interaction involving the factors "Test group" and "Line location", *F*(1,17)=5.748, *p*<.028). That interaction was however accounted for by the Session X Test group X Location interaction which was also significant, *F*(3,51)=4.29, *p*<.009. As illustrated in Figure 3, baboons from the OPEN+ group performed better with the OUT lines than with the IN lines, and this difference was reliable in session 3 (Tukey *HSD*, *p*<.05). The CLOSE+ group had a reduced performance over sessions in the OUT trials, but an increased performance with continuing testing in the IN trials (see Figure 3). From them, the difference between the IN and OUT condition was significant for session 4 (Tukey *HSD*, *p*<.05).

Insert Figure 3 about here

Discussion

Two main findings emerged from Experiment 2. The first one is that the line ends are critical aspects of the stimuli allowing discrimination of open/close shapes in baboons. Consideration of the end points for discrimination is demonstrated by a reduced performance when the stimuli contain added line segments with highly visible end lines. The second important result is that the weighting assigned to this feature is different in the two test groups. This conclusion is firstly supported by the fact that the OPEN+ group was more disrupted by the added end lines than the CLOSE+ group. It is also supported by the significant line Location X Session interaction obtained for the CLOSE+ group. That interaction indicates that this group paid particular attention to the inner part of the stimuli early in Experiment 2, and was consequently more impaired by the IN than the OUT lines. This effect did not emerge in the OPEN+ group, suggesting that the inner part of the stimuli was not that important for this group.

Experiment 3

The contributions of two new factors were tested in Experiment 3. The first one is the alignment of the end points (collinearity) in the open stimuli. According to the Gestalt principles (Grossberg & Mingolla, 1985; Kirkpatrick, Wilkinson & Johnston, 2007; Quinn & Bhatt, 2009), the alignment should be a salient stimulus dimension that may contribute to the global shape of the stimulus, and may therefore control the discrimination between the open and close shape. The second experimental factor is the visual appearance of the line ends that were either sharp of smooth. If baboons based their responses on the presence / absence of end lines, then their performance should deteriorate with the smooth end lines. It was expected that these experimental manipulations will help identifying the processing strategies adopted by the OPEN+ and CLOSE+ groups to solve the task.

Method

Participants and apparatus. They were the same as in Experiment 1, in addition to one 22-year old female baboon (B08) who had already been trained in the same conditions as for the other baboons in Experiment 1. B08 was assigned to the CLOSE+ group.

Stimuli. Figure 1 (panel c) illustrates the stimuli. The stimulus set consisted in 64 new polygons or curvilinear shapes which were drawn considering the same principles as in Experiment 1. The two end points of the open stimuli were either aligned or misaligned, and in addition either sharp of smooth. Smoothing the end point was done using the “blending tool” of Adobe Photoshop. There were 16 open shapes in each alignment (aligned, misaligned) by type of end point (sharp, smooth) condition.

Test procedure. It was in its general principle identical to Experiment 1. The OPEN+ and CLOSE+ groups of baboons were both tested in 4 test sessions of 256 trials each. Each test session comprised 192 baseline trials randomly intermixed with 64 probe trials (using the 16 probe trials for each condition of alignment X type of end point). These probe trials consisted in one presentation of each new open shape which was paired with the same shape presented in its closed version. The left right locations of S+ in the baseline and probe trials were balanced across trials. The other procedural aspects of the task were as in Experiment 1**.**

Results

The performance was statistically above chance (50% correct) in the probe trials (mean correct = 82.79%, *SD* = 3.77%, paired t-test, *t*(19)=36, *p*<.01), but it remained below that of baseline trials (mean correct = 94.33%, *SD* = 2.31%, paired t-test, *t*(19)=9.97, *p*<.01). The performance decrement in probe trials, in comparison to baseline trials, suggests that alteration of the end point properties disrupted the discrimination between the closed and open forms.

An ANOVA assessed the effect of Test group (OPEN+, CLOSE+), Session (n=4), End point alignment (aligned, misaligned), End point type (sharp, smooth), and their interactions on discrimination scores. There was a main effect of end point type, *F*(1,18)=15.16, *p*<.001, as well as a main effect of alignment, *F*(1,18)=71.48, *p*<.001. These two main effects were however accounted for by two reliable two-way interactions involving the Test group as a factor (Test group X End point type: *F*(1,18)=13.98, *p*<.002; Test group X alignment: *F*(1,18)=7.21, *p*<.015). Post hoc comparisons (Tukey *HSD* tests, *p<.05*) showed that end point type had no detectable effect on the performance of baboons from the CLOSE+ group, but affected performance of the OPEN+ group. Baboons of this last group obtained lower performance for the smooth end points, in comparison to the sharp end points (see Figure 4). By contrast, the use of misaligned end points decreased performance level in both groups, but the performance decline was significantly stronger (Tukey *HSD* test, p<.05) for the CLOSE+ group than for the OPEN+ group.

Insert Figure 4

Discussion

This experiment suggests important differences in the way baboons from the OPEN+ and CLOSE+ groups solved the open/close discrimination problem. Baboons from the

OPEN+ group proved strongly sensitive to the appearance of the points, which is a local dimension of the stimuli. This effect of end points suggests a featural mode of processing of the task for these subjects. By contrast, the baboons from the CLOSE+ group showed no reliable effects of end points, but they were more sensitive to the misalignment of the terminal segments of the open shapes than their counterparts. Findings from this group therefore demonstrate that the animals from that group had an enhanced sensitivity to the configural properties of the stimuli, in comparison to the OPEN+ group. In short, the OPEN+ group appears more feature-orientated than the CLOSE+ group, which pays greater attention to the configural properties of the stimuli.

Experiment 4

Experiment 4 used a visual search paradigm to further explore the hypothesis of a qualitative difference in the processing of the task between the OPEN+ and CLOSE+ groups. That last experiment was inspired from Treisman & Souther (1985). These authors requested human adult to search for an open circle among closed circles, or vice versa, in the context of a visual search task. They reported a search asymmetry: the RTs were faster when the participants had to identify an open circle among closed circles than in the opposite condition (see also Reiffenrath, Heller & Jacobs, 1991). Treisman & Souther (1985) assumed from their findings that two different search procedures mediated target detections in the two tasks. Based on the analysis of the search slopes in the two conditions, they argued that the subjects detected preattentively the line ends of the gap when searching for an open circle among closed distractors. By contrast, they would attend in priority the target contour when searching for a closed target. According to the authors, that latter strategy implies an attentional (serial) processing of the display, as revealed by a significant increment of RTs with display size.

Experiment 4 tested if a search asymmetry similar to Treisman & Souther (1985) can be replicated in baboons. We used the same two groups of baboons as before, which were now tested with a visual search task. In this new study, baboons from the CLOSE+ were requested to detect the closed target among a variable number of open shapes serving as distractors. Performance obtained in this task was compared to that of the OPEN+ group tested in the opposite situation (open target and closed distractors). The comparative analysis of the search slopes was expected to shed light on the processing of the open and closed stimuli by these two groups.

Method

Participants and apparatus. The same tests systems and participants were the same baboons as in Experiment 1, with the exception of both Michelle and B08 who were no more available for testing.

Stimuli. The stimuli were the same 20 open shapes as in Experiment 1, and their closed version, but their size was reduced 130 X 130 pixels for a possible simultaneous display of several stimuli on the screen.

Procedure. Each trial started with a yellow cross appearing centrally in the bottom of the screen. That cross served as a fixation stimuli. Touching that cross triggered the display of 1, 2, 4 or 8 stimuli on the screen. As shown in Figure 5, one of these stimuli was the target, the others were distractors. Stimuli and distractors had identical shapes but differed by the presence or absence of a gap in their contour. All stimuli were distributed randomly on an imaginary 4 x 2 grid. To avoid a systematic alignment on the grid, their location was also randomly jittered within each cell of the grid by a maximum of 30 pixels in both axes. In response to these displays, the baboons had to identify the target and to touch it. Touching the target provided a food reward, while an inappropriate selection of one of the distractors delivered a 3-s time out during which the screen turned green. As with the previous experiments, the open shape served as the target for the baboons of the OPEN+ group. In turn, the closed shape served as target for the members of the CLOSE+ group.

Insert Figure 5 about here

Before testing, baboons were trained during 3 sessions of 100 trials that only used the target (no distractor). After training, the two groups of baboons were presented with 8 test sessions of 480 trials each. Each test session comprised 120 trials per display size (1, 2, 4 and 8) which were presented in a random order. Both scores and RTs were recorded in each trial. The RTs were defined as the time elapsed between the onset of the test display and the actual touch of one of the stimuli on the screen.

Results

Scores. The number of correct responses per baboon and display size were entered into a Test group (CLOSE+, OPEN+) X Display size (1, 2, 4 and 8) two-way ANOVA. The ANOVA showed a main effect of Test group, $F(1,16)=17.37$, $p<.001$, a main effect of Display size, $F(3,48)=64.59$, $p<.001$, and an interaction between Test group and Display size, $F(3,48)=24.99$, $p<.001$. This latter interaction is depicted in Figure 5. As shown in that Figure, there was a decline of performance with increasing display size that was stronger for CLOSE+ than OPEN+ group. Post hoc comparisons (Tukey *HSD* test, $p<.05$) indicated that the baboons from the OPEN+ group performed better than the other group with display sizes of 4 and 8 (see Figure 5).

Insert Figure 5 about here

RTs. Median RTs for correct responses were calculated for each baboon and display size (see Figure 5). They were analyzed considering the Hick's law (Hick, 1952). That law predicts that decision times should increase linearly when the number of stimuli (n) in the display (i.e., number of choices) is converted to bit units using the function $\log_2(n+1)$. We therefore converted display sizes to bits(display size 1 = 0 bit, 2 display size 2 = 1 bits, display size 4= 2 bits, display size 8 = 3 bits) and analyzed the linear relations between RT and bits. The slope of the function indicates if the amount of bits of information interfered with the basic processing cost of the task given by the intercept value.

Least-square best fitting functions offered very good approximations of average median RTs. In all our analyses, more than 98% of the variance was accounted for by the linear function, suggesting that the RTs followed the Hick's (1952) law. The slope of the linear function between RTs and bits was 186.4 ms/bit for the OPEN+ group. Interestingly, that slope was reliably steeper (203.3 ms/bit) for the CLOSE+ group (*F*(1,16)=41.58, *p*<.001) suggesting that it was more demanding to search for a closed shape among open distractors. The analyses of intercept showed by contrast reliable higher processing cost of the task (*F*(1,16)=30.08, *p*<.001) for the OPEN+ (541.6 ms) than for the CLOSE+ group (311.2 ms).

An ANOVA assessed the effects of Test group (CLOSE+, OPEN+) and bits (0, 1, 2 and 3) on median RTs. It showed a main effect of Test group, *F*(1,16)=8.86; *p*<.009, a main effect of bits, *F*(3,48)=227.28, *p*<.001. The effect of Group revealed faster responses on average for OPEN+ than for CLOSE+ group. There was also a significant Test group x bit interaction, *F*(3,48)=40.23, *p*<.001. Post hoc comparisons (Tukey *HSD* test, *p*<.05) showed that for the OPEN+ group, median RTs only differed between the 0, 1 and 2 bit conditions. There was no statistical difference between the 2 and 3 bit conditions. The result was as follows for the CLOSE+ group: 0 bit < 1bits < 2bits < 3bits. Moreover, median response times were significantly faster for the group OPEN+ than for the CLOSE+ group the 2 and 3 bits conditions.

Discussion

Experiment 4 allows two main conclusions. First, baboons performing a visual search task showed RTs that followed the prediction of Hick's (1952) law. That is, there was a positive association between RT and bits of information processing demand, a finding consistent with other reports using related chronometric approaches to the measurement of selective attention (e.g., Deruelle & Fagot, 1998). According to Treisman & Gelade's (1980) *feature-integration* theory, this pattern of results suggests an attentional processing of the displays in both groups of baboons, which likely adopted a serial search strategy to find the target. Second, great differences emerged between the OPEN+ and CLOSE + groups, although both groups demonstrated the Hick's law. This difference corresponds to a much steeper slope for CLOSE+ group than the OPEN+ group. Of the most importance, this difference cannot be accounted for by a speed-accuracy trade-off, as the positive linear relation between RT and bits was found in a context where the baboons showed a performance decrement with increasing display sizes. Considering Treisman & Gelade's (1980) feature integration theory, this finding demonstrates that it is more attention demanding for the baboons to locate a closed target among open targets (CLOSE+ group) than to find an open target among closed distractors (OPEN+ group).

Stated differently, Experiment 4 revealed that it is easier for baboons to detect a gap in the contour than to detect its absence. Formulated in this way, our findings are reminiscent of the *feature-positive (FP) / feature-negative (FN) effects* as described in ??. FP/FN effects concern discrimination learning when two discriminative stimuli differ by the presence or absence of a single feature. Discrimination learning is typically easier (FP effect) for feature positive than for feature negative discrimination problems. In that latter case the discrimination is much slower and sometimes failed. This asymmetry in learning was first reported in pigeons (Jenkins and Sainsbury, 1969, 1970) and was also demonstrated in primates (Pace, McCoy and Nallan, 1980), rats (Crowell & Bernhardt, 1979) and humans (Newman, Wolf & Hearst, 1980). In the context of our research, the hypothesis can be proposed that steeper search slopes for the CLOSE+ group reflects FN, as the baboons from that group had to report the absence of the gap in target's contour. This hypothesis was investigated in Experiment 5.

Experiment 5

The aim of Experiment 5 was to explore if FN/FP effects can account for the results obtained in Experiment 4. The logic of Experiment 5 was to use the same general protocol as in Experiment 4, namely a visual search task, except that the targets and distractors now differed by the presence or absence of single well defined feature which was different from a gap in the stimulus contour. In that last experiment, the monkeys had to report the presence or absence of small vertical line segments on the target stimulus. Because the use of open or closed shapes stimuli was impossible due to potential conflicts with discrimination learning achieved in Experiments 1-4, the discriminative features were displayed on a horizontal lines in that new experiment. The analysis of the results compared the intercepts and slopes of the functions relating RTs and bits in the two experiments. It was reasoned that intercept differences between Experiments 4 or 5 should reflect variations in basic processing costs that may be explained by differences in stimulus or general display complexity. It was further reasoned that different search slopes in Experiments 5 and 4 should indicate the contribution of FP/FN effects to the results of Experiment 4, and if there are additional processing constraints when the task imply the task implies the discrimination between open and closed forms.

Method

Participants and apparatus. The tests systems were the same as in previous Experiments. The participants were the same as before, with the exception of of B03, B05, B06, B07, B11 and B15 which were no more available for testing.

Stimuli. The experiment used 21 stimuli. One first stimulus was a horizontal (130 X 7 pixel) line (Figure 7). The remaining 20 stimuli consisted in the same line to which a small vertical segment (20X7 pixels) has been added in 20 possible different equidistant locations (see an example in Figure 7). All stimuli were yellow drawings displayed on a black background.

Procedure. The procedure was the same as in Experiment 4. On each trial, the baboons firstly touched a yellow cross appearing centrally in the bottom of the screen. That action triggered the display of 1, 2, 4 or 8 stimuli on the screen. The stimuli were displayed on the screen following the same constraints as in Experiments 4. One of the stimuli was the target, the others were distractors. The target and distractors systematically differed by the presence or absence of the small vertical line. The subjects belonging to the OPEN+ group in Experiment 4 were requested to touch the stimulus containing the vertical segment (condition “FP). Those of the CLOSE+ group were to touch the stimulus devoid of line segments (condition FN). The other aspects of the task, for instance in terms of reinforcement contingencies, were identical to Experiment 4.

Before testing, baboons were trained during 3 sessions of 100 trials that displayed the target in absence of distractors. After training, the two groups of baboons were presented with 8 test sessions of 240 trials each. Each test session comprised 60 trials per display size (1, 2, 4 and 8, corresponding to 0, 1, 2 and 3 bits, respectively) presented in a random order.

Results

All the analyses reported below only considered the baboons who have participated to both Experiments 4 and 5.

Scores. The number of correct responses for each display size in the two groups of baboons are depicted in Figure 6 (panel a). As expected, a decrease of mean performance is observed with increasing display size. A two-way ANOVA considered the effects of Test group (FP/FN, corresponding to the previous OPEN+ and CLOSE+ groups) X Bit (0, 1, 2 and 3) on scores. That analysis revealed no score difference between the FP (OPEN+) and FN (CLOSE+) groups, but a main effect of bit, $F(3,30)=15.21$, $p<.001$, and an interaction between Test group and Bit, $F(3,30)=6.12$, $p<.002$. The main effect of Bit is accounted for by a reduced performance for displays of 3 bits than for displays of 0 bit (Tukey *HSD* test, $p<.05$). Moreover, performance of FN group was higher than those of FP group when the display only contained 1 bit of information (Tukey *HSD* test, $p<.05$).

Insert Figure 6 about here

RTs. Median RTs for correct responses are illustrated Figure 6 (panel b). An ANOVA on the median RTs assessed the effects of Test group (FP,FN) and Bits (0, 1, 2 and 3). It revealed no reliable effect of group, but a reliable effect of Bits ($F(3,30)=111.67$, $p<.001$), as well as a significant Test group x Bit interaction, $F(3,30)=16.52$, $p<.001$. For the FP (OPEN+) group, post hoc comparisons (Tukey *HSD* test, $p<.05$) revealed the following pattern of results: 0 bit < 1 bit < 2 bits <3 bits conditions. For the FN (CLOSE+), the 0<2<3 pattern was obtained. Median response times for display size of 3 bits were also faster for the FP (OPEN +) than for the FN(CLOSE+) group.

The slopes of the function relating RTs and display size (expressed in bits) was of 108s/bit (r^2=) for the FN (CLOSE+) group and 53ms/bit (r^2=) for the FP (OPEN+) group (??? % of the variance accounted for by these linear functions). Individual slopes were submitted to a one-way ANOVA with the Test group as the unique between subjects factor. The slope was steeper for the FN(CLOSE+) than for the FP(OPEN+) group, $F(1,10)=14.77$, $p<.003$. A similar ANOVA performed on the intercept revealed shorter intercepts for the FN(CLOSE+, mean 300 ms, *SD* = 42 ms) group than for the FP(OPEN+) group (mean = 381 ms, *SD*=43), *F*(1,10)=10.67, *p*<.008) .

Comparisons between Experiments 4 and 5. Two separate ANOVAs were computed on intercepts and slopes, considering Test Group (CLOSE+, OPEN+) and Experiments (Experiment 4, Experiment 5) as factors. The analysiseof te intercept revealed a main effect of Test Group (*F*(1, 10)=26.47, *p*<.001), a main effect of Experiment (*F*(1, 10)=12.34, *p*<.006) and an interaction between these two factors (*F*(1, 10)= 33.20, *p*<.001). For the CLOSE+ group, post hoc analyses (Tukey test *HSD*, *p*<.05) revealed no significant intercept differences between Experiments 4 and 5 (Experiment 4: 262.99 ms, *SD*= 51.1; Experiment 5: 299.91 ms, *SD*=42.4). For the OPEN+ group, the intercept was however reliably faster in Experiment 5 than in Experiment 4 (Experiment 4: 533.1 ms, *SD*=104; Experiment 5: 380.8 ms, *SD*=43.4).

The two-way ANOVA on slopes revealed that the main effects of Test Group (*F*(1, 10)=52.7, *p*<.001), Experiments (*F*(1, 10)=188.3, *p*<.001) were significant. Interestingly, however, their interaction was also significant (*F*(1, 10)= 56.0, *p*<.001). For the CLOSE+ group, slopes were equal to 286 ms/bit (S*D*=48) in Experiment 4, and 108 ms/bit, (*SD*=28) in Experiment 5. The slope obtained in Experiment 4 was thus steeper than in Experiment 5 by a ratio of 2.65. The same effect emerged for the OPEN+ group, but slope differences were reduced in that group. The slope was equal to 106 ms/bit (*SD*=22) in Experiment 4, and 53 ms/bit (*SD*=19) in Experiment 5, and was thus steeper in the former experiment by a factor of 2.

Discussion

Hence, in these two experiments, slopes were steeper for the CLOSE+ group than for the OPEN+ groups, indicating that processing for search a closed form among open ones or that processing for search a stimuli lacking a feature among stimuli containing a feature was more attentional demanding than their respective opposite search rules. Slopes found in Experiment 4 were steeper than in Experiment 5. Then the processing cost of the task was higher when feature was a gap or an open contour than when it was a simple small line segment.

nt.

Discussion

The aim of Experiment 5 was to establish if the presence or absence of only one feature in a pair of stimuli can revealed a FP effect in baboons using a visual search asymmetry procedure. In accuracy level terms,

Results of Experiments 5 revealed that baboons from the OPEN+ group outperformed

General discussion

Four experiments were conducted in this research to assess the discrimination of closed from open shapes by baboons. Investigating that issue was considered important in nonhuman primates, because closure is a critical cues in humans for contour grouping and figure-ground segmentation (Elder & Zucker, 1993, 1994, 1998; Hadad & Kimchi, 2008; Kimchi, 2000; Kovacs & Julesz, 1993; Marino & Scholl, 2005; Pettet, McKee & Gryswacs, 1998; Saarinen & Levi, 1999). This issue has received in addition very little attention in the animal literature (but see in pigeons, Allan & Blough, 1989; Kirkpatrick, Wilkinson & Johnston, 2007). Baboons were requested in our research to discriminate open from closed shapes in the context of two alternative forced choices (Experiments 1-3) or visual search

(Experiment 4) protocols. That discrimination problem can be defined in two ways. The participants may firstly look for the critical feature distinguishing the open from the closed shape, namely the presence of end points delimiting gap in the contour. Doing so implies a featural mode of processing with an attention focused on the local details of the shape. The alternative strategy is to search and process closeness *per se*. That mode of processing requires that the attention moves away from features for the processing of the configural properties of the shape.

Whether nonhuman primates process in priority the featural or configural properties of displays remain a debated issue. On the one hand, there is an abundant literature suggesting that they process in priority the local features in hierarchical stimuli (De Lillo et al., 2005; Deruelle & Fagot, 1998; Fagot & Deruelle, 1997; Fagot & Tomonaga, 1999; Hopkins & Washburn, 2002; Spinozzi et al., 2006; Spinozzi et al., 2003). On the other hand, other studies, mostly using faces, suggest that they attend in priority the configural stimulus properties (Dahl, Logothetis, & Hoffman, 2007; Parr, Heintz & Akamagwuna, 2006; Parr & Heintz, 2008). Several aspects of our research support the first hypothesis of a local mode of processing, but these supports mostly derive from the OPEN+ group. First, baboons from the OPEN+ group learned the task in Experiment 1 faster than those of the CLOSE+ group, suggesting that the stimulus properties defining openness (i.e, end lines) are more salient than those defining closure. Second, though limited to the first experimental session, performance of the OPEN+ group exceeded that of CLOSE+ group during the test trials of Experiment 1. Third, adding new end lines to the display in Experiment 2 was distractive, and rendered detection of the target end lines more difficult. Fourth, degrading the visual properties of the local feature by smoothing the end lines disrupted their discrimination in Experiment 3. Finally, search times were faster on average in Experiment 4 for the OPEN+ group than

CLOSE+ group, indicating that the end lines were rapidly detected by the OPEN+ group. All these results raise issues regarding the saliency of closure cues as perceptual primitives in baboons. They suggest that closure is not such a salient dimension for the baboons. This mere result can explain why the baboons preferred to process in priority the end lines defining openness.

The second important conclusion of our research is that the two groups differ in their processing of the stimuli, and that the CLOSE+ baboons are more oriented toward the processing of the configural properties of the stimuli than the OPEN+ group. The following three results support this conclusion : (1) the baboons from the CLOSE+ group required more additional training sessions than the OPEN+ group in Experiment 1 when the size of the gap was reduced, suggesting that the members of this group attended the configural arrangement (i.e., their separation) of the two end lines. (2) In Experiment 2, adding new line segments to the displays affected negatively and reliably the performance of the OPEN+ group, but this effect was limited to the polygonal shapes for CLOSE+ group. This result suggests that the CLOSE+ group processed cues, presumably configural cues, other than the end points. (3) Alteration of the end point properties in Experiment 3 had no detectable effect on the performance of the CLOSE+ group, suggesting a lack of processing of the end point appearance. By contrast, change in the end point alignment more drastically disrupted their performance, which further ascertains a configural processing of the global shape. This latter result converges with the human literature also showing the importance of good continuation and collinearity in closure processing (Biederman, 1987; Hadad &Kimchi, 2008; Kimchi, 2000; Pettet, McKee, & Grzywacz, 1998; Spehar, 2002). Although the above findings show that baboons from the CLOSE + group paid greater attention to the configural cues than those of the OPEN+ group, it should not be concluded that their processing of configural cues was exclusive of the processing of featural cues. The fact that the CLOSE+ baboons process featural cues in addition to configural cues is for instance demonstrated by a performance decrement in that group, when line segments (features) were added to the stimuli in Experiment 2.

In a different perspective, it is noticeable that the OPEN+ test groups systematically outperformed the CLOSE+ group, when the end points remained unaltered in Experiments 1 and 4. This finding demonstrates that the processing of features is a more efficient strategy, presumably of a lower level of cognitive complexity, than the processing of configural closure. Several lines of research involving humans support the notion that configural processing is of a higher level of cognitive complexity than featural processing. Mori (1997) demonstrated for instance that the search for a closed target was dependent upon closure information of global configuration. Because this shape property is too complex to be extracted at a low level of visual processing, it was thought to be constructed at a higher level of processing which incorporates primitive features into perceptual representations of shapes and objects (Tversky, Geisler & Perry, 2004). In addition, human brain imaging studies have both reported that feature analysis mostly activate the primary visual areas (Dumoulin & Hess, 2006; Kourtzi & Huberle, 2005), while configural analyses activates associative areas (e.g., Doniger et al., 2000; Sehatpour, Molholm, Javitt, & Foxe, 2006). Contrary to the claim of early Gestalt psychologists, it can be concluded from our study that closure is not a perceptual primitive for baboons as it was also demonstrated in humans. The primitive would rather be the presence of end points which are present for the open forms but absent from the closed forms.

À reprendre pour discussion : Spinozzi, De Lillo, & Castelli (2004) found that capuchins didn't identified the different stimulus parts of a sample complex pattern when the parts can be assembled on the basis of grouping principles, such as closure and good continuation.

In more general terms, the most important contribution of our study is to demonstrate that the mode of closure processing strongly

depends on the training conditions, and is therefore fluctuates across individuals. The debate on the processing of configural cues in nonhuman primates is mostly aimed to provide a yes or no answer to the question "are monkeys capable of processing configural cues" (e.g., Fagot & Deruelle, 1997), but this now seems an inappropriate reasoning. A more adequate reasoning is to conceive that their spontaneous tendency to process stimulus features in priority might be flexibly altered in favor of a greater consideration of configural cues, depending on the nature of the task and training contingencies.

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Figure Captions

Figure 1: Illustration of the stimuli used in Experiment 1 to 3. (a) : stimuli used in Experiment 1; (b) : stimuli used in Experiment 2; (c) : stimuli used Experiment 3.

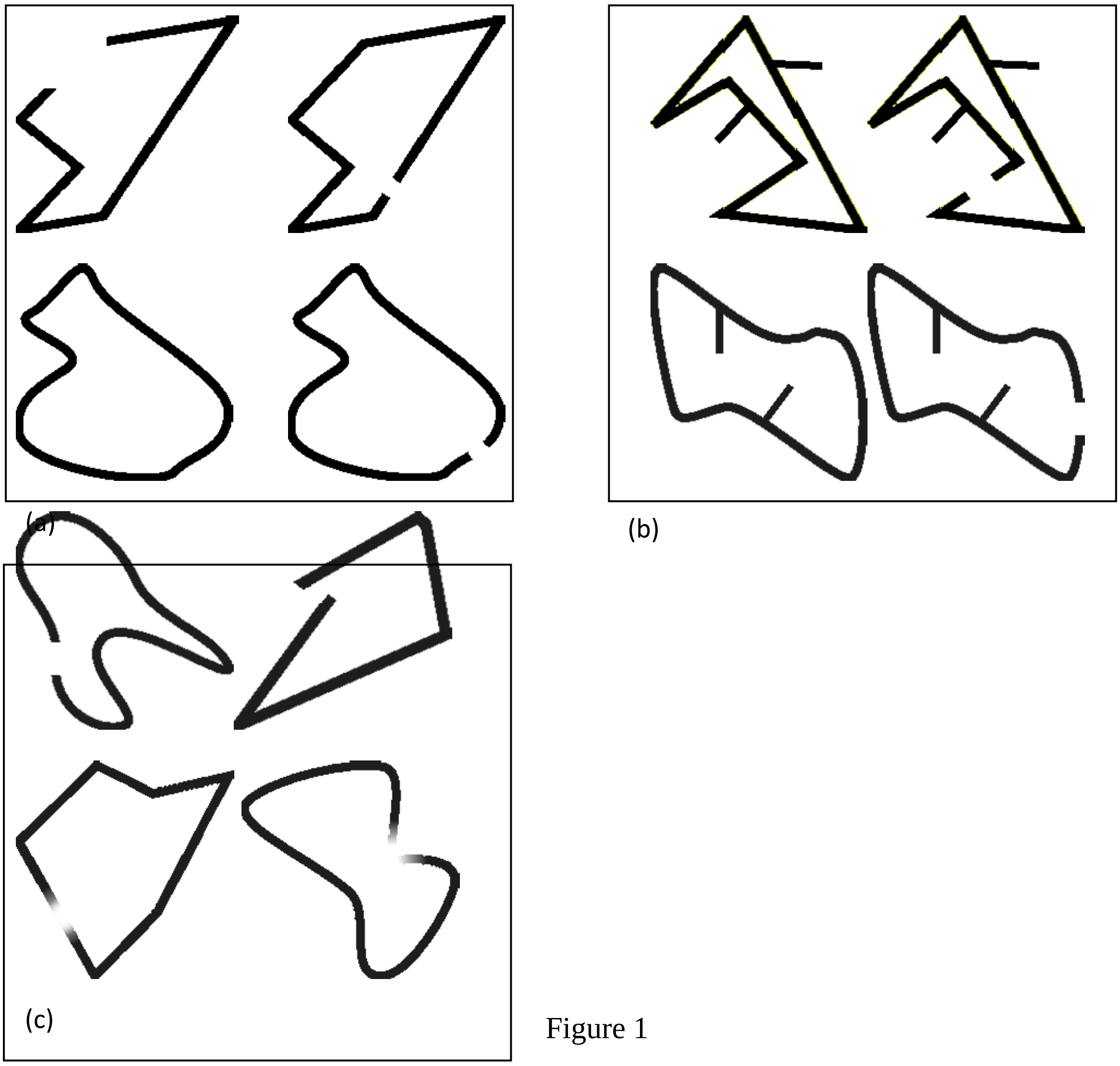
Figure 2: Mean performance ofthe OPEN+ and CLOSE+ groups, depending on the presence or absence of added lines in Experiment 2 (a) with curvilinear shapes, (b) with polygonal shapes.

Figure 3: Experiment 2 : mean performance in the four test sessions, as a function of the location of the added lines (IN our OUT) of (a) OPEN+ and (b) CLOSE+.

Figure 4: Experiment 3 : mean performance of the two groups of baboons with sharp and smooth end points (a) and with aligned and misaligned end points (b).

Figure 5: Illustration of the displays used in Experiment 4 : above, open target; under, closed target.Figure 6: Mean of performance and means search times for each group as a function of the number of items per display in Experiment 4 (above) and Experiment 5 (under).

Figure 7: Illustration of the pair of stimuli used in Experiment 5


(a)

(b)

(c)

Figure 1

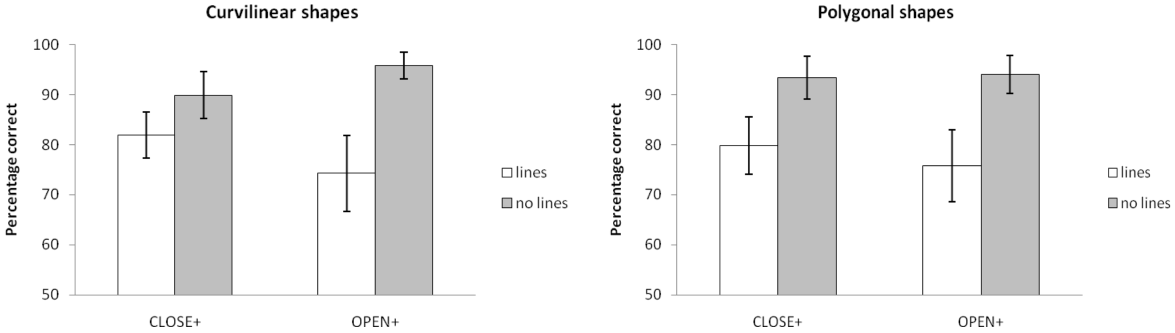

Curvilinear shapes
Polygonal shapes
Percentage correct
100
90
80
70
60
50
CLOSE+
OPEN+
□ lines
▨ no lines

Figure 2

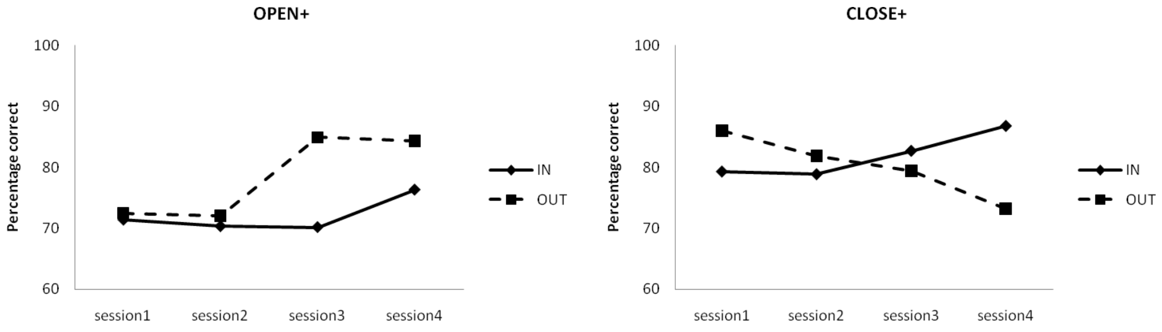

OPEN+
100
90
80
70
60
Percentage correct
session1
session2
session3
session4
IN
OUT
CLOSE+
100
90
80
70
60
Percentage correct
session1
session2
session3
session4
IN
OUT

Figure 3

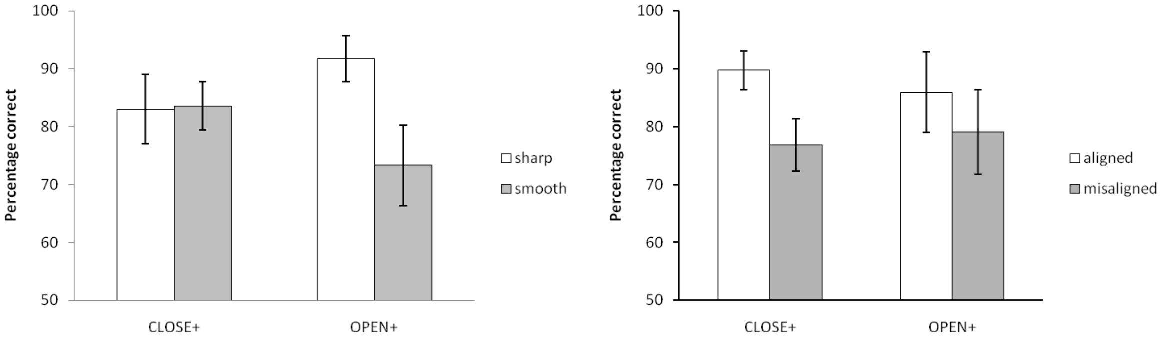

100
90
80
70
60
50
Percentage correct
CLOSE+
OPEN+
□ sharp
▨ smooth
100
90
80
70
60
50
Percentage correct
CLOSE+
OPEN+
□ aligned
▨ misaligned

Figure 4

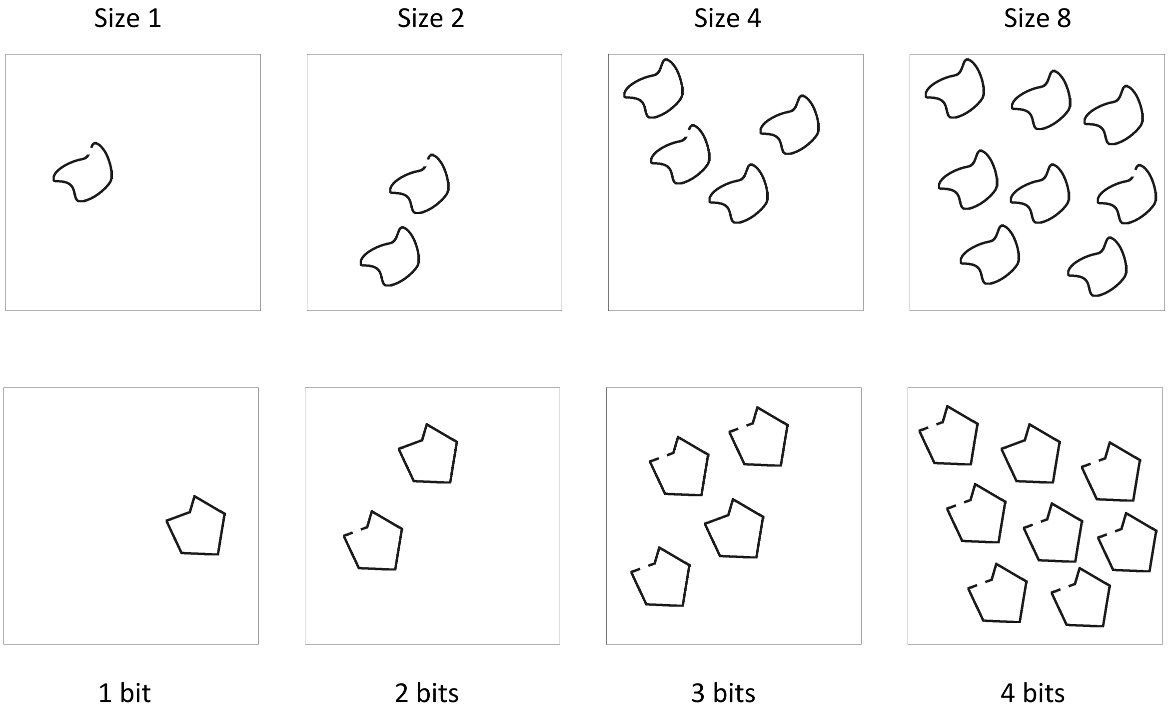
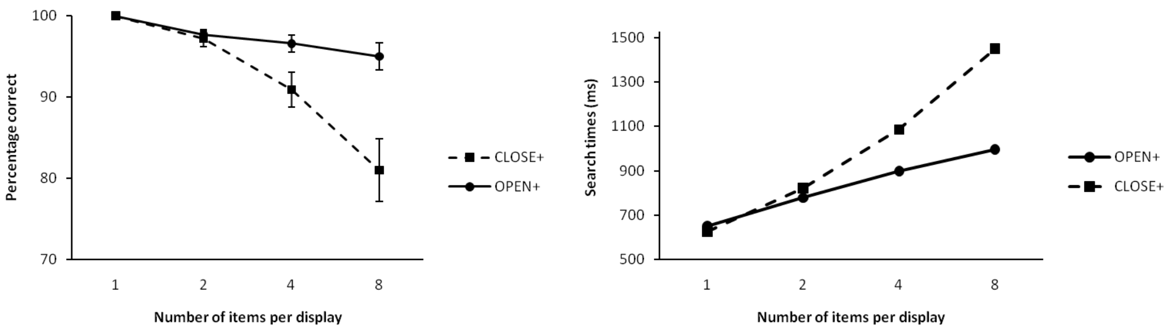


Figure 5

Experiment 4: Open / closed



Experiment 5: Feature/ no-feature

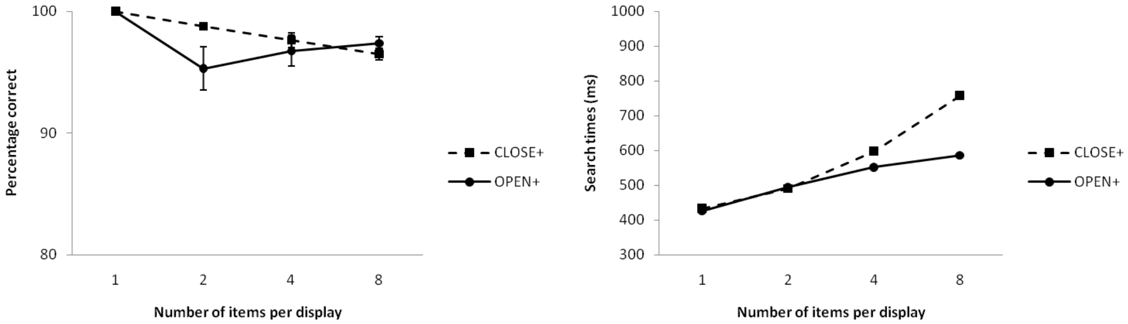


Figure 6