

**Fission-Fusion Dynamics,
Behavioral Flexibility,
and Inhibitory Control in Primates**

Federica Amici, Filippo Aureli, and Josep Call

Supplemental Experimental Procedures

The experimenter always sat in front of the subject, outside the testing room. A plastic table was placed between the experimenter and the testing room, and raisins, seeds or small pieces of banana were used as rewards.

Task 1: the A-not-B error task

Three opaque plastic cups were aligned on the table. We followed the procedure used by Piaget [3]. Each session consisted of 4 trials. At the beginning of each trial, the experimenter opened the three cups to show the subject that they were empty by letting them rest on one side. Then, in full view of the subject, she baited one of the two exterior cups (cup A) and then closed all the cups, covering the food. The table was then pushed towards the subject, so that the subject could make a choice. The subject could only choose one cup by touching it. The same cup was baited and the procedure repeated, until the subject had made the correct choice for three consecutive trials, otherwise the session was interrupted and administered at a later time. The first and the third trials for all sessions (including the interrupted sessions) were considered the control trials, and were regarded as successful if the subject correctly chose the baited location. On the fourth trial, cup A was baited again. After all the cups had been closed the experimenter, always in complete view of the subject, opened cup A, retrieved the food, closed the cup again and placed the food under the

opposite exterior cup (cup B). The fourth trial was considered the experimental trial. The experimenter scored whether the subject could inhibit choosing the previously baited location (cup A), and instead correctly choose the cup to which the food had been transferred (cup B). Each monkey subject participated in 18 sessions, randomly starting by baiting the most right or the most left cup and counterbalancing the position of the reward within the task, without repeating it more than three times in a row. Great apes had been tested by Barth & Call [4] for 1 session.

Task 2: the middle cup task

Three opaque plastic cups were aligned on the table. We followed the procedure used by Call [5]. At the beginning of each trial, the experimenter opened the three cups to show the subject that they were empty, by letting them rest on one side. Then, in full view of the subject, she placed two food rewards in front of two of the three cups (one reward in front each of the two cups), and then closed all the cups, covering the food. The table was then pushed towards the subject, so that the subject could choose two cups, by touching them. There were two conditions. The experimenter either baited two cups next to each other (adjacent condition or control condition), or the two exterior cups (non-adjacent condition or experimental condition), thereby leaving the middle cup unbaited. The experimenter scored whether the subject correctly chose the baited cups in both conditions, inhibiting the intermediate action to select the middle cup in the non-adjacent condition. Each monkey subject participated in 18 trials for each condition, randomly alternating the two different conditions and counterbalancing them within the task, without repeating the same condition more than three times in a row. Great apes had been tested by Barth & Call [4] for 2 sessions.

Task 3: the plexiglas hole task

A transparent plexiglas panel (about 65 cm wide and 50 cm high, with two holes on it, one at the right bottom side and one at the left bottom side, both wide enough to allow each subject to stick its arm through them) was standing upright on the ground between the subject and the experimenter. It was fixed in such a way that the subject could only reach for the food, by sticking an arm through one of the two holes. Each session consisted of 7 trials. In the first trial, the experimenter placed one piece of food directly on the plastic table, in front of one of the two holes. She then pushed the table towards the subject, and let the subject retrieve the food by sticking an arm through the hole. The experimenter repeated the procedure five more times, counterbalancing the position of the food between the two holes within each session, in a randomized fashion. The first and the sixth trials were considered control trials. On the seventh trial, the experimenter placed the food on the plastic table, but now in the middle of it, between the two holes. She then pushed the table towards the subject, and let the subject retrieve the food. The seventh trial was considered the experimental trial. The experimenter scored whether on the first attempt the subject tried to reach the food directly through the plexiglas panel, or took a detour movement through one of the holes. All monkeys participated in 18 sessions, while great apes had been tested on 2 sessions [J. Call, unpublished data].

Task 4: the swing door task

A box made of transparent plexiglas was placed between the subject and the experimenter, outside the testing room but within the subject's reach. The box had two transparent doors facing the subject only opening towards the inside. Behind these doors, there were two little shelves to place the food. If the subject tried to reach for the food by pushing the door directly in front of the food, the food fell and the subject could not get it anymore. The size of each door easily allowed the subject to stick the arm through it, to reach for the food placed behind the other door. The food was

perfectly visible from the outside. A lateral sliding door allowed the experimenter to replace the food after the subject had taken it. We followed the procedure used by Vlamings [6]. The experiment consisted of only one stage. The subjects needed no previous training, apart from some time to acquire confidence with the empty box. Before each trial started and hidden from the subject, the experimenter placed a piece of food behind one of the two doors, randomly alternating the position of the food (left or right) without repeating it more than three times in a row. The experimenter scored whether on the first attempt the subject inhibited the action of reaching directly for the food, thus making it fall, by instead sticking an arm through the other “empty” door, to reach the food through a detour-movement. Each subject participated in 20 trials, 10 on the first day and 10 on a following day. Great apes had been tested by Vlamings [6] for 10 trials.

Task 5: the delay of gratification task

The experimenter presented two different amounts of food (1 or 3 pieces) to the subject. We followed the procedure used by Rosati *et al.* [7]. Each session consisted of 14 trials. The first 4 trials were forced-choice trials, because the subject could not choose between two different amounts of food, but was only presented with one. In these trials, the amount of food presented (1 or 3 pieces) and its position (right or left) was randomly chosen and counterbalanced within the 4 trials of each session. The food was pushed towards the subject, who had 60 seconds to retrieve it by trying to reach for it. When the subject was presented with 1 piece of food, the experimenter let him immediately retrieve it; when the subject was presented with 3 pieces of food, the experimenter let the subject retrieve them only after a certain delay of time, determined according to the subject’s performance in the previous session (see below). When the subject completed all the 4 forced-choice trials, the experimenter run 10 free-choice trials. In these trials, the subject was simultaneously

presented with two different amounts of food (1 and 3 pieces), the position of which (right or left) was randomly chosen and counterbalanced within the 10 trials of each session, without repeating it more than three times in a row. The food was pushed towards the subject, who had 60 seconds to make the choice by trying to reach for the food. The smaller reward was always available immediately, while the larger reward was available immediately in the first session and then adjusted according to the subject's performance in the previous session (see below). As the subject made a choice, the experimenter removed the non-chosen reward and let the subject immediately retrieve the food in case of 1 piece or after the delay in case of 3 pieces. During the delay period, the experimenter sat looking motionless before letting the subject retrieve the food. If a subject chose the same side at least eight times on the free-choice trials, the subject was considered to have a side bias, so the session was concluded and repeated on another day. If a subject completed 4 consecutive sessions with a bias on the same side, prior to the next session the subject received 6 forced-choice trials on the not-chosen side, randomly alternating the presented amount of food (1 or 3 pieces). Within each session, the delay was always held constant. Before incrementing the delay for the first time, the subject had to choose the larger reward at least 9 times (out of the 10 free-choice trials), in two consecutive sessions. After these two sessions, the delay for the larger reward was incremented according to the subject's performance in the previous session. If the subject had chosen the larger reward in 8 to 10 free-choice trials, the delay was incremented by 10 seconds; in 6 to 7 free-choice trials, the delay was incremented by 5 seconds; in 5 free-choice trials, the delay was kept the same; in 3 to 4 free-choice trials, the delay was diminished by 5 seconds; in 0 to 2 free-choice trials, the delay was diminished by 10 seconds. The experimenter scored which reward was chosen by the subject in each trial. Each subject was tested until reaching the indifference point. Bonobos and chimpanzees had been tested by Rosati *et al.* [8].

Subjects

All subjects were housed in well-established groups in enclosures with outdoor and indoor areas. Apart from spider monkeys and one gorilla, who were wild born, all the other subjects were born in captivity. All subjects were used to being temporally isolated in the area of their enclosure where the tests were carried out (testing rooms) and were tested by familiar experimenters (the first author in most cases). Apart from spider monkeys, all subjects had previously participated in experimental tasks but none of them had previously been tested on the present tasks. All subjects except spider monkeys were familiar with plexiglas barriers. Indeed, most of the spider monkey subjects seemed extremely scared of plexiglas when first exposed to it (vocalizing, jumping and refraining to approach it). Consequently, before testing them on tasks involving this material, we hanged a plexiglas panel inside the testing room for several days, so that the subjects could get used to it. No experiments were conducted during this habituation period. Before and during testing, subjects were not deprived of food or water at any time. Each subject was tested individually. In those cases in which the subject was reluctant to be isolated, another individual was present and the trial was only started and completed when there was no interference by the other individual. Not all subjects were tested in each task, but they were always a combination of sexes, various ages and dominance ranks.

Table S1. Subjects participating in this study.

<i>Subject</i>	<i>Species and testing location</i>	<i>Sex</i>	<i>Age</i>	<i>Rank</i>	<i>Tests</i>
1	Spider monkeys,	F	S	L	AB; MC; PH; SD; DG
2	at the Centenario	F	S	M	AB; MC; PH; SD; DG
3	Zoo in Merida,	M	S	H	AB; MC; PH; SD; DG

4	Mexico	M	S	M	AB; MC; PH; SD; DG
8		F	A	H	AB; MC; PH; SD; DG
9		F	A	L	AB; MC; PH; SD; DG
11		F	A	M	AB; MC; PH; SD; DG
21		M	A	H	AB; MC; PH; SD; DG
22		M	A	H	AB; MC; PH; SD
23		M	A	M	AB; MC; PH; SD; DG
24		F	S	L	AB; MC; PH; SD; DG
26		F	A	L	AB; MC; PH
31		F	A	H	AB; MC; PH; SD; DG
32		F	A	M	MC; DG
34		M	A	M	MC
Old 3		M	A	L	MC
Old 7		F	S	H	AB; MC; PH
Old 9		F	A	L	AB
Brahms	Capuchin monkeys, at the ISTC-CNR Primate Centre in Rome, Italy	F	A	L	AB; MC; PH
Cognac		M	A	H	AB; MC; SD; DG
Narciso		M	A	H	PH
Pandora		F	A	M	AB; MC
Panna		F	A	M	AB; MC
Paquita		F	A	M	SD; DG
Patè		M	A	H	AB; MC; PH
Pedro		M	S	H	AB; MC; SD; DG
Penelope		F	S	M	AB; MC; SD; DG
Pepe		M	A	H	AB; MC; PH; SD; DG
Pippi		F	A	L	AB; MC; PH; SD; DG
Punk		F	A	M	AB; MC

Quincey		F	J	M	SD; DG
Roberta		F	A	M	PH; SD; DG
Robin Hood		M	A	H	AB; MC; DG; PH; SD
Robinia		F	A	H	AB; MC; PH
Robiola		F	A	L	PH
Robot		M	A	M	AB; MC; PH
Rosso		M	A	M	AB; MC
Rubens		M	S	L	SD; DG
Rucola		F	S	L	AB; MC; PH
Sandokan		M	S	H	SD; DG
Saroma		F	S	M	AB; MC; PH
Viola		M	A	M	AB; MC; PH
Virginia		F	S	L	PH
Vispo		M	S	H	AB; MC; PH; SD; DG
Zapotec		M	A	H	AB; MC; PH
Anastasia	Long-tailed macaques, at the University of Utrecht, Netherlands	F	J	L	AB; MC; PH; SD; DG
Cleo		M	A	H	AB; MC; PH; SD; DG
Cornea		F	A	M	AB; MC; PH; SD; DG
Era		F	A	H	AB; MC; PH; SD; DG
Icetea		F	A	M	AB; MC; PH; SD; DG
Linea		F	S	H	AB; MC; PH; SD; DG
Logica		F	S	L	AB; MC; PH; SD; DG
Ofelia		F	J	L	AB; MC; PH; SD; DG
Salvadoro		M	J	L	AB; MC; PH; SD; DG
Sea		F	A	M	AB; MC; PH; SD; DG
Video		M	S	H	AB; MC; PH; SD; DG
Zargasso		M	J	L	AB; MC; PH; SD; DG

Dorien	Chimpanzees, at the Wolfgang Koehler Primate Research Center, Leipzig Zoo, Germany	F	A	H	PH
Fifi		F	A	M	PH
Fraukje		F	A	M	PH
Frodo		M	A	H	PH
Jahaga		F	A	L	PH
Riet		F	A	H	PH
Sandra		F	A	M	PH
Trudi		F	A	L	PH
Joey	Bonobos, at the Wolfgang Koehler Primate Research Center, Leipzig Zoo, Germany	M	A	M	PH
Kuno		M	A	L	PH
Limbuko		M	A	M	PH
Ulindi		F	A	H	PH
Bimbo	Orangutans, at the Wolfgang Koehler Primate Research Center, Leipzig Zoo, Germany	M	A	H	PH; DG
Dokana		F	A	M	DG
Dunja		F	A	M	PH; DG
Kila		F	S	L	DG
Padana		F	A	M	PH; DG
Pagai		M	J	L	DG
Pini		F	A	H	PH; DG
Raja		F	J	L	DG
Toba		F	A	M	PH
Walter		M	A	H	PH
Bebe	Gorillas, at the Wolfgang Koehler Primate	F	A	M	PH; DG
Gorgo		M	A	H	PH; DG
Kibara		F	J	L	DG

Ndiki	Research Center, Leipzig Zoo, Germany	F	A	H	PH
Nkwango		M	A	M	PH
Ruby		F	A	L	PH
Viringika		F	A	M	PH; DG

Sex (M=male; F=female); age class (A=adult; S=subadult; J=juvenile; according to the literature [1,2]); dominance rank (H=high; M=middle; L=low; according to differential access to juice and food); and the administered tasks (AB=A-not-B error; MC=middle cup; PH=plexiglas hole; SD=swing door; DG=delay of gratification).

Supplemental References

1. Smuts, B.B., Cheney, D.L., Seyfarth, R.M., Wrangham, R.W., and Struhsaker, T.T. (1987). Primate Societies (Chicago: University of Chicago Press).
2. Kappeler, P.M., and Pereira, M.E. (2003). Primate Life Histories and Socioecology (Chicago: University of Chicago Press).
3. Piaget, J. (1954). The Construction of Reality in the Child (New York: Basic Books).
4. Barth, J., and Call, J. (2006). Tracking the displacement of objects: A series of tasks with great apes (*Pan troglodytes*, *Pan paniscus*, *Gorilla gorilla*, and *Pongo pygmaeus*) and young children (*Homo sapiens*). J. Exp. Psychol. 32, 239–252.
5. Call, J. (2001). Object permanence in orangutans (*Pongo pygmaeus*), chimpanzees (*Pan troglodytes*), and children (*Homo sapiens*). J. Comp. Psychol. 115, 159-171.
6. Vlamings, P. (2006). Inhibition in Great Apes: Performance on a Detour-Reaching and Reversed Contingency Task. Master thesis (University of Maastricht).

7. Rosati, A.G., Stevens, J.R., and Hauser, M.D. (2006). The effect of handling time on temporal discounting in two New World primates. *Anim. Behav.* 71, 1379-1387.
8. Rosati, A.G., Stevens, J.R., Hare, B., and Hauser, M.D. (2007). The evolutionary origins of human patience: Temporal preferences in chimpanzees, bonobos, and human adults. *Curr. Biol.* 17, 1663-1668.

Figure S1. Graphical representation of interspecific pairwise comparisons between species based on the mean ranks assigned to each individual across the five tasks. Grey segments represent a significant difference ($p < 0.01$) between the species listed on the left column and the species listed on the top row. Empty spaces indicate no significant differences in pairwise comparisons.

