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Mental Map in Wild Chimpanzees: An Analysis of Hammer Transports for Nut Cracking

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ABSTRACT. The mental map of wild chimpanzees is analyzed in the context of their transports of clubs and stones used for cracking two species of nuts of different hardness, *Coula edulis* and *Panda oleosa,* in the Tai National Park (Ivory Coast). For the harder *Panda* nuts, they transport the harder hammers, i.e., almost exclusively stones, hammers of greater weight, and the transports are longer than for *Coula* nuts. The analysis made for the transports for *Panda* nuts shows that they seem to remember the location of stones and to choose the stones so as to keep the transport distance minimal. The chimpanzees seem to possess an Euclidian space, which allows them to somehow measure and remember distances; to compare several such distances so as to choose the stone with the shortest distance to a goal tree; to correctly locate a new stone location with reference to different trees; and to change their reference point so as to measure the distance to each *Panda* tree from any stone location. They also combine the weight and the distance. The wild chimpanzees of the Tai National Park seem to possess concrete operation abilities in spatial representation.

INTRODUCTION

The mental map of young chimpanzees has been studied by MENZEL (1973, 1974, 1978, 1979) on a small group of subadult animals in a 1-acre enclosure. He shows that these chimpanzees, in searching for hidden food, maximize the rate of food acquisition by using a least-distance strategy. This knowledge of distances was also combined with the ability to measure angles, allowing them to find out the hidden place of food, symmetrically opposed to another one with reference to the release cage. In this report we analyze the mental map used by wild chimpanzees when transporting stones to crack nuts in the Tai National Park (Ivory Coast).

The interesting psychological questions on mental maps in animals are not *whether* they exist, but *how* exactly the individual maps reality and derives behavioural rules from them. In the present study we are, however, not concerned with these questions; we simply report a natural field situation where the existence of a spatial mental map can be demonstrated. The stone hammers are particularly favourable objects for such a study: they are rare, imperishable, transportable, always on the ground where the observer can see them and have a neatly defined function. Most natural food sources offer few of these advantages.

METHODS

This study was made from 1979 to 1983 on wild chimpanzees *(Pan troglodytes verus)* in the tropical rain forest of the Tai National Park, Ivory Coast. The community of chimpanzees studied comprises about 70 individuals which live in a home range of 27 km^2. Due to the very low visibility in this dense forest (at most 20 m), the habituation process was very slow, not progressing visibly during the first two years and still remaining incomplete in 1983 with the females and their dependent offspring. The chimpanzees crack five species of nuts, but we collected data for only two of them, *Coula edulis* and *Panda oleosa.* Impulse measures showed that to open a *Panda* nut requires a blow about five times stronger than a *Coula* nut. The nuts are placed on an anvil, an emerging root or an outcropping rock. They are pounded with a hammer, i.e., a wooden club, usually part of a fallen branch, or a stone. Stone hammers weigh from about 0.5 to 18.0 kg and decrease in hardness from granite to quartzite and laterite (for description, availability, choice of materials and description of the behaviour see BOESCH & BOESCH, 1981, 1983). Transports of hammers between the anvils of the different trees are frequent.

Coula trees are very abundant in this forest, occurring mostly on crests, each tree is usually within sight of several others. *Coula* nuts can easily be opened with clubs, which are most frequently used to pound them, followed in frequency by granite and laterite stones. *Coula* trees being so abundant, we followed the hammer transports for them only in some restricted areas of about 6 km^2, rich in *Coula.* Here we knew the different anvils and the locations of clubs and stones well, and although, usually, we did not see the transport itself, we could record it when we found a particular hammer on another anvil than before, with fresh nut shells on the new anvil. How often a shift was the result of several subsequent transports is not known, but the most likely interpretation is that only one transport was involved.

Panda trees, in contrast to *Coula* trees, are widely scattered and much rarer. *Panda* nuts are very hard and can only be opened with stones. All the *Panda* trees in three selected *Panda* regions (about 5 km^2) within the home range were individually marked and numbered, and all the stones found on their anvils were weighed and individually marked with dots. Stones being a rarity in this forest, it is unusual to find one elsewhere than on an anvil. Such stones were marked as well. Thus, we could follow precisely the transported stones between the different *Panda* trees. The distances were measured in straight lines, using a 20-m rope. Our inspections were so frequent that an inferred transport dated back at most three days.

RESULTS

Table 1 summarizes all transports of hammers used for cracking both nut species, recorded During four nut seasons. The hammer types transported differ greatly for the two nut species (clubs versus stone hammers: $x^2 = 415.26$, $df = 2$, $p < 0.001$, and granite versus laterite hammers: $x^2=57.59$, $df = 1$, $p < 0.001$; 2x2 contingency table, SIEGEL, 1956).
The chimpanzees transport hammers according to the hardness of these nuts;
for the softer *Coula* nuts they often transport clubs, whereas for the hard *Panda* nuts they transport almost exclusively stones and mostly the harder granite stones.

Table 1. Transport frequencies of different types of hammers for Panda and Coula nuts, in four nut seasons.

Table 1. Transport frequencies of different types of hammers for *Panda* and *Coula* nuts, in four nut seasons.

Hammers carried to anvils of	Club	Granite	Laterite	Total
Coula nuts	258	111	70	439
Panda nuts	3	401	54	458

C. Table 2. Weight and distance of transports of hammers used for *Panda* (Pa) and *Con/a* (Co) in four nut seasons.

	0-5m		5-20m		20-50m		50-200m		200-500		+500m		Total	
	Pa	Co	Pa	Co	Pa	Co	Pa	Co	Pa	Co	Pa	Co	Pa	Co
Granite:														
0.0-0.9kg	3	-	6	3	-	-	1	-	-	-	-	-	10	3
1.0-2.9kg	15	13	10	8	5	10	4	10	4	-	1	2	39	43
3.0-8.9kg	46	4	37	16	19	7	52	1	12	-	-	-	166	28
+9.0kg	26	1	15	-	3	-	3	-	1	-	-	-	48	1
Laterite:														
0.0-0.9kg	6	8	1	15	-	7	-	1	1	-	-	-	8	31
1.0-2.9kg	1	5	2	4	2	1	1	-	3	-	-	-	9	10
3.0-8.9kg	-	-	1	3	4	1	2	-	-	-	-	-	7	4
+9.0kg	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clubs:	3	94	-	90	-	9	-	-	-	-	-	-	3	193
Total	100	125	72	139	33	35	63	12	21	-	1	2	290	313

Table 2 shows the weight and the distances of hammers transported for *Panda* nuts (Pa) and *Coula* nuts (Co) in four years.The chimpanzees adjust both, the weight of the stone hammer and the transport distance to the nut species. They transport heavier stones (x^2-= 94.66, *df* = 3, $p < 0.001$) and make longer transports ($x^2 = 26.53$, *df* = 4, $p < 0.001$) for the hard *Panda* nuts than for *Coula* nuts. For *Coula* they transport stone hammers over longer distances than clubs (x^2= 67.74. *df* = 4, $p < 0.001$). This latter observation could, however, result purely from the much higher density of available clubs than of stones.

When testing for correlations between the weight of granite hammers and the distance of the transport of these stones, we found that for *Panda,* the chimpanzees carry heavier hammers over longer distances than light hammers (Kendall coefficient of concordance *W* 0.62, $p < 0.05$; SIEGEL, 1956); no correlation is found for *Coula.* Since an optimal *Panda* hammer is heavier than an optimal *Coula* hammer, we can conclude that the chimpanzees are prepared to carry an optimal tool over a longer distance than a suboptimal one, as if they compared the benefits and the costs of various choices.

The results also suggest that the decision process of transporting a hammer for *Coula* seems less complicated than for *Panda.* The chimpanzees crack *Coula* nuts mostly in groups (BOESCH & BOESCH, in prep.) and in areas rich in *Coula* trees. These abundant trees are at visual distance of each other and the chimpanzees walk from one straight to the next. Tool transports are frequent; we saw 112 cases where a chimpanzee took along the hammer it had just used, carried it while searching the ground for nuts, and used it again on another anvil, farther in the direction of the group's movement. Such transports are not necessarily planned *before* making them. It can happen that a chimpanzee takes along the hammer and simply drops it after a few meters (17 observations), either because it changed its mind or because the group leaves the *Coula* area. Chimpanzees that crack first on the ground and then in a tree or vice-versa (20 observations) do not require much planning of action either. The hammer is chosen in the presence of the nuts and the tree, and planning remains a simple association process. In fact, hammer transports for *Coula* are made mostly over short distances (85% over 20 m or less) and do not involve a complex decision process.

For *Panda,* 40% of the transports are made between trees *out of sight* of each other, i.e., more than 20 m apart. Moreover, the animals crack *Panda* nuts mainly alone or in pairs (BOESCH & BOESCH, in prep.); the group does not provide a fixed direction, so that the crackers choose the transport direction themselves. These aspects make the transport decisions for *Panda* more complicated than the ones for *Coula.* We shall analyze in detail the transports of more than 20 m between different *Panda* trees. Out of 117 transports, 76 were selected for this analysis, because they all fulfill the following conditions: (1) Transports were made in one of the three fawJa-sample areas of the home range where we know individually all the *Panda* trees and stones and their location; and (2) all available stones in a circle of 300-m radius around the goal tree were known to us at the time the transport was made, and their distance to the goal tree was measured in a straight line. We ascertained that none of the stones known to us had been mislaid away from any anvil, and as well as possible that no new, unknown stone had appeared in the area before the moment of the transport (only four new stones appeared in the *Panda* areas, three during the second year and one in the fourth year). As we checked all stone locations at least every third day, it is unlikely that we missed many transports. We probably did so three times when shells of freshly cracked nuts were found on an anvil without a stone on the way between the two trees where we had recorded the stone. Chimpanzees may transport stones to *Panda* trees that already have one; this was the case in 12 out of the 76 transports for reasons we shall discuss later.

The chimpanzees could use two alternative strategies for these transports: (1) *Random search strategy:* They might take any stone they find and carry it to any *Panda* tree; and (2) *Mental map strategy:* They might use a mental map of stones and trees to minimize the transport distance, the weight of the stone, or the energy (weight x distance).

In Table 3 the 76 selected transports are classified with reference to these parameters. In order to illustrate the procedure, we detail in Table 4 some examples of the 76 transports, indicating the available stones in a 300-m radius around the goal tree for each case. The situation can be visualized in Figure 1, which represents the main *Panda*-sample area with all the *Panda* trees between which the transports of Table 4 were made.

Of the 76 cases, 48 transports were made of the nearest stone, 26 of the lightest one and 40 of the least energy demanding one. The following first analysis starts from the assumption that a chimpanzee first selects a tree and then the stone that is optimal for a transport to that tree rather than vice versa. Can we reject the hypothesis that the transported stone was chosen at random for either the distance, the weight or the energy? The probability depends only on the number of stones present in the 300-m circle, since we disregard stones outside it. The total mean probability of choosing the optimal stone for one of the three criteria by chance

Table 3. Stone transports of more than 20 m classified according to three possible minimized parameters.

Minimal distance	Minimal weight	Minimal energy1)	No. of transports
+	+	+	17
+	-	+	21
+	-	-	10
-	+	+	2
-	+	-	7
-	-	-	19

1) Concordance between these parameters. The transports are classified for each parameter as + if they were minimized for it, otherwise they were classified as —.

was calculated *as* $p = 0.262$, composed of the mean probability $p = 0.50$ in the 17 cases where two stones were present in a circle of 300 m around a goal tree, $p = 0.33$ in the 7 cases with three stones,$p = 0.25$ in 9 cases with four stones, $p = 0.20$ in 11 cases with five stones, $p= 0.16$ in 11 cases with six stones, $p = 0.14$ in 11 cases with seven stones and $p = 0.12$ in 10 cases with eight stones. The observed probability for the minimal distance was $p = 0.631$. The random search strategy must therefore be rejected ($x^2 = 53.69$, $df = 1$, $p < 0.001$). The random search strategy is also rejected against the minimal energy hypothesis (observed probability $p = 0.526$; $x^2 = 27.42$, $df= 1$, $p < 0.001$), but not against the minimal weight strategy (observed probability $p = 0.342$; $x^2 = 2.52$, $df=1, p > 0.05$).

Table 3 shows that 95 % of the transports that are optimal for energy ($z = 13.05$, $p < 0.001$) are also optimal for distance, whereas only 47 % of the energy-optimal transports ($z = 0.38$, $p > 0.05$) are also optimal for weight. Therefore, the least-distance principle seems to rule the chimpanzees' decision. It is important to note that a chimpanzee transporting a stone above about 3 kg walks on three limbs and carries the stone in one arm; this change in locomotion seems a strong argument in itself for a least-distance strategy. Still, the high con-

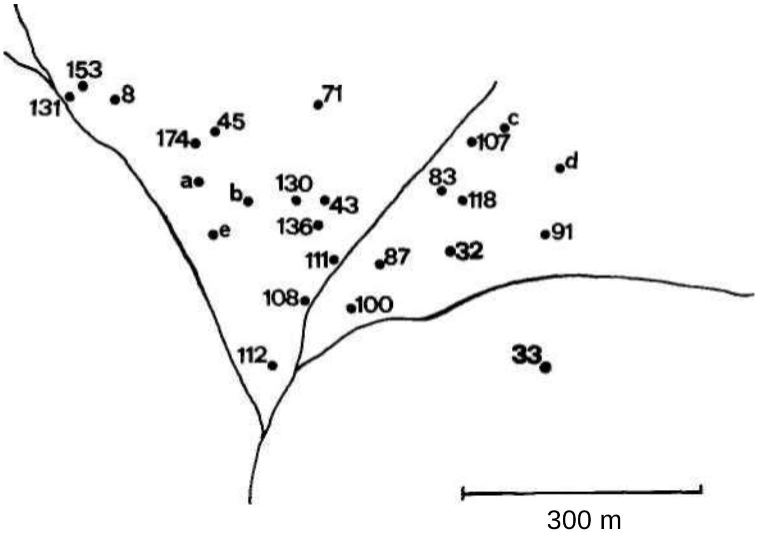

Fig. 1. Sample area in which the transports of stone hammers listed in Table 4 were recorded. *Panda* trees, indicated as dots and identified by numbers, are abundant in this area, a, b, c, d, e are ateliers with stone hammers not situated under *a Panda* tree. The river system is the Odrenisrou.

Table 4. A sample of transports of stone hammers to *Panda* trees in the region of Figure 1.*

	Trans.	Start	Goal		2nd			3rd			4th			5th			6th			7th		
No.	stone	tree	tree	m	stone	loc	m	stone	loc	m	stone	loc	m	stone	loc	m	stone	loc	m	stone	loc	m
1.	G 2.4	a	45	50	G 2.0	131	185	G 3.8	108	195	G 5.2	111	220	G 5.6	87	260	G 6.0	100	285	G11.4	100	285
2.	G 5.8	118	85	30	G 3.6	107	75	G 5.6	87	108	G 3.8	43	130	G 2.4	43	130	G 5.6	100	200	G 6.0	100	200
3.	G 5.2	100	130	130	G 9.8	100	130	G 5.8	83	145	G 3.8	112	150	G 3.6	107	190	G 5.6	91	300			
4.	G 3.6	8	174	110	G 3.8	b	110	G 1.4	136	180	G 9.8	87	280	G 5.8	83	290	G 5.2	100	300			
5.	G 9.8	100	87	80	G 5.8	83	110	G 5.2	130	130	G 5.6	91	160	G 3.8	b	170	G 3.6	c	300	G 2.6	71	300
6.	G 5.2	87	33	235	G 5.6	87	240	G 6.0	100	250	G 9.8	100	250	G 5.8	d	250						
7.	G 3.8	108	136	95	G 6.0	100	100	G11.4	100	100	G 5.6	87	110	G 2.4	45	250	G 5.8	d	250	G. 2.6	71	250
8.	G 5.8	d	118	128	G 5.6	87	120	G 3.8	43	150	G 6.0	100	200	G 9.8	100	200	G 5.2	33	230	G 3.6	71	285
9.	G 5.6	87	91	155	G 5.8	83	125	G 3.8	107	200	G 5.2	100	240	G 9.8	100	240						
10.	L 2.3	e	45	125	G 5.2	45	0	G 3.6	131	210	G 3.8	100	230	G 9.8	100	230						
11.	G 3.1	87	100	80	G 5.6	100	0	G 9.8	87	80	G 3.6	130	130	G 5.6	44	135						
12.	G 5.2	136	87	108	G 5.6	87	0	G 6.0	100	90	G 9.8	100	80	G 2.4	45	250	G 2.6	71	250	G 5.8	d	250
13.	G 3.6	71	107	195	G 5.8	118	75	G 2.4	43	170	G 3.8	43	170	G 5.6	87	185	G 5.2	100	240	G 6.0	100	240
14.	G 5.6	91	100	240	G 3.6	130	130	G 5.2	71	270	G 3.1	45	280									
15.	G 5.2	43	100	120	G 9.8	87	80	G 1.4	136	100	G 5.8	83	186	G 5.6	91	240	G 3.6	c	300	G 2.6	45	300

*Nos. 1–7 are least-distance transports; 6–9 rule three situations; 10–12 are transports to trees already with a stone; 11-15 are suboptimal transports. The available stones in the vicinity of goal tree are located and their distance to the goal tree indicated (see text for further explanations).

cordance of optimal weight to optimal distance (65% of the minimal weight transports are also optimal for the minimal distance) is striking and will be discussed later.

Before that we shall analyze the role of distance. A transport can be made in three different sequences: (1) As in the above assumption, the chimpanzee finds a *Panda* tree with nuts and then searches the nearest stone, or the two nearest stones, if two chimpanzees crack together. Jn that case, when there is already a stone at the anvil, the additional one must be the nearest one; (2) the chimpanzee finds a stone and carries it to the nearest *Panda* tree with nuts. In this situation, two animals can crack together only if the chosen tree already has a stone at its anvils; and (3) the chimpanzee thinks in advance about its actions and adapts its path so as to pick up the stone nearest to the *Panda* tree where it wants to crack nuts, before arriving at this tree.

To differentiate between (1) and (3), we must be able to follow the chimpanzees before they transport the stones. As this is still impossible, we must leave (3) aside; we assume, then, that a chimpanzee actually visits the goal tree before fetching the optimal stone. Table 5 gives the results of the 76 transports analyzed for (1) and (2). (1) and (2) can easily be differentiated : For example, for the transport No. 3 of Table 4, the nearest stone to the *Panda* tree 130 was the 5.2 kg stone situated at the *Panda* tree 100. If the chimpanzee had primarily chosen to work with that stone rather than at a particular tree, the nearest tree with nuts to this stone would have been *Panda* tree 87 that was only 80 m away. We thus reanalyze the 76 transports with reference to the original site of the transported stone rather than to the site of the goal tree. The analysis shows that when the tree is the nearest to the stone, the stone is mostly also the nearest to the tree (84%, $z = 5.24$, $p < 0.001$), in other words, the former is rarely true alone while the latter often is. It seems that the chimpanzees transport stones according to sequence (1) and that some transports, by chance, happen to be optimal also under (2). A chimpanzee typically first selects a tree—either by actually going there or mentally—and then the optimal stone, suggesting that tool quality might be less crucial than tree quality.

The results of Table 3 indicate that weight does not play a decisive role in the chimpanzees' evaluation. Nevertheless, as mentioned above, distance *and* weight are simultaneously optimal in 65% of optimal weight transports. To test the hypothesis that weight plays a secondary role at certain distances, we analyzed the following situations: (I) In situations where at least two stones were situated less than 20 m from the same *Panda* tree, we regularly noted which one was used at the anvils of this tree, in order to learn about the weight preferred for hammering. When only one stone was used, the chimpanzee took the heavier one in 32 cases out of 46 ($x^2 = 7.04$, $df = 1$, $p < 0.01$). This regularity shall be called rule I (Table 6); and (2) in situations of a stone being transported over more than 40 m from a *Panda* tree that had at least two stones of different weight at its anvils (example No. 3 in Table 4), they took the lighter one in 18 cases out of 22 ($x^2 = 8.90$, df=1. $P = 0.01$). The chimpanzees prefer lighter stones when the distance of transport increases (rule 2 of Table 6).

These two results show that the chimpanzees incorporate the weight of the hammer in their choice and combine it with the transport distance. On this basis, we shall analyze a third situation: (3) In 16 of the 76 transports, the situations were analyzed in which there was a small (< 25%) difference of transport distance (both over 40 m) between the two nearest stones, and in which those two stones belonged to the same or adjacent weight classes (examples Nos. 6-9 in Table 4). In these cases, the chimpanzees chose the nearest stone in 10

Table 5. The long stone transports classified according to the two possible sequences of action.*

Finding the nearest stone to a tree	Finding the nearest tree to a stone	No. of transports
+	+	27
+	−	21
−	+	5
−	−	23

*When the situation prior to the transport corresponds to one of the sequences, the transport is classified as +.

cases out of 16 ($x^2 = 1.00$, $df = 1$, $p > 0.05$). The chimpanzees also chose the lighter stone in 10 out of the same 16 cases (same statistics). Both differences are not significant; the chimpanzees seemed to choose indifferently between two stones at comparable distance and of comparable weight (rule 3a of Table 6).

We propose to summarize the relative roles of weight and distance by four rules (see Table 6).

If we analyze the 76 transports under the criteria of the four rules, 52 or 68 % of the transports are optimal. This result shows that the chimpanzees use a mental map that allows comparing distances; in some cases they also combine them with the weight of the hammer.

It is difficult to sort out all the reasons which might induce the chimpanzees to make sub-optimal transports, but social reasons probably contribute: (1) In the main study area (Fig. 1), we distinguished six different chimpanzees that regularly cracked *Panda* nuts. The fact that at least six animals use probably the same stones can provoke suboptimal transports, as they are certainly not always aware of the stone transports made by the others; and (2) twelve out of the 76 transports were made to *Panda* trees already having a stone at their anvils (examples Nos. 10 to 12 of Table 4), and in 10 of these cases at least two chimpanzees were supposed to have cracked there together, judging by the remains of freshly cracked nuts at the anvils on which the stones were placed. Only in two of these ten cases did we actually see the two chimpanzees crack together and these transports were counted as optimal, as the two stones used were the nearest and second nearest ones. For the other eight cases, we judged on the basis of the shells alone. In these cases of presumed social interferences, the least-distance principle seems less strictly followed by the chimpanzees, as only three out of these eight transports were optimal under our rules. We hope that the progress of habituation of the chimpanzees will allow to study these social interferences in the future.

Table 6. Four rules that summarize the interactions of the transport distance and the weight in the chimpanzees' evaluations.*

Rule	Transport distance	Difference between the distances	Relationship between the weights	Hammer choice
1	<20m	None	Different	Heavier
2	>40m	None	Different	Lighter
3a	>40m	<25%	Same	Indifferent
3b	>40m	>25%	Different	Lighter
4	>40 m	<25%	Same or different	Nearer

*For each rule, we describe the relations of distance and weight between the two nearest stones to the goal tree (see text for further explanations).

DISCUSSION

The indirect method we adopted in this study, due to the slow habituation of the chimpanzees towards us, will leave many questions open: How do chimpanzees find a stone at a specific location? Do they only use topographical references which could be confusing in this homogenous dense forest? Or do they use some knowledge of general directions? How do they remember all the stone locations precisely enough to make their evaluations? The most energy demanding methods would be to check all the possible anvils before deciding. Our personal experience shows that it can take hours to check them all in order to find a specific lost stone. This method would be at least very time consuming. If we accept that they remember the stone locations, we must also assume that they do check them to follow their movements due to transports made by other chimpanzees. Still, we do not know for how long they remember these locations.

Regardless of the sequence in which the chimpanzee brings stone and tree together, the fact remains that he or she nearly always brings the stone nearest to a goal tree, even though he or she can only see either the stone or the *Panda* tree at the same time. This requires the following mental operations: (1) *Measurement and conservation of distance:* Chimpanzees have a system of spontaneous measure of distance between two objects (stone-tree) in the forest. The measure they use for this distance is mostly independent of what and how many objects happen to be situated between the two objects (e.g., different tree species, fallen trees or small rivulets), and it remains constant whatever the locations of the animals are. Furthermore, the measure is sufficiently precise and independent of direct sensory input to perform the next operation with results that most often are comparable to those we obtain by our map and 20-m rope; (2) *Comparisons of several distance:* The abstraction of these distances (five on the average) oriented differently in space allows the chimpanzees to manipulate them mentally, in order to compare them and to sort out the shortest distance to the goal tree. The situations of rule 3 show that they begin to seriate them according to their length, in order to know the two shortest ones of which the weight will be compared; (3) *Permutation of objects in this map:* Newly transported stones are placed correctly in their mental map with reference, at least, to all the *Panda* trees to which transports will be aimed; and (4) *Permutation of the point of reference:* The distances associated to a stone are not invariant, but the set of distances between the stones and one tree can be mentally exchanged by a set relating the same stones to another tree.

The simultaneous presence of these four operations requires an evolved mental map. Using the Piagetian criteria, all these four operations belong to the concrete operations period. The Piagetian school (PIAGET & INHELDER, 1972; PIAGET et al., 1973) distinguishes three levels of spatial representation in the human child: the topological, the projective and the Euclidian ones. The topological space uses only qualitative relations: one object is seen as part of another, or as enclosed by another, or as proximal versus distant to another object. At most three objects can be related. The projective space, in addition, takes into account the notions of angles and directions, and describes relations as seen from, different points of view. The Euclidian space adds to the former spaces the notion of distances through the capacities of measuring, remembering the exact distance regardless of one's point of view and integrating this space. Thus, the Tai chimpanzees seem to demonstrate an Euclidian mental map, using straight lines to measure distances. And "…if it is a matter of comparing several distances oriented in all directions, we should bring in the measure: only the measure, characteristic of the next level, stage ITIB (concrete operations are divided into stage III A and B).

will allow the achievement of the complete system of references or coordinates" (PIAGET et al., 1973 by our translation). Stage **IIIB** appears around the age of nine years in the human child.

MENZEL'S group of chimpanzees, consisting of subadult individuals, already demonstrated a mental map developing along parallel trends to the Tai chimpanzees. It is difficult to make comparisons as MENZEL'S chimpanzees were tested in a much easier environment, with all the landmarks they used visible from all points of the enclosure, whereas Tai chimpanzees have only 20 m of visibility. Thus, Tai chimpanzees must work much more with mental representations. Nevertheless, MENZEL'S chimpanzees demonstrate a general knowledge of distance also using a least-distance principle and an accurate memory of up to 18 food locations, although the time they had to remember it was short.

These highly developed faculties demonstrated by Tai chimpanzees agree with other results, shown by the adult female, *Sarah* (WOODRUFF et al., 1978), who possesses the capacity of conserving quantities, which is also a concrete operation. It is not surprising that other authors (HALL et al., 1980) failed to find these operations as they tested it on juvenile chimpanzees of 5.5 years old, whereas they appear only between 6-7 years in humans. Evaluating the intelligence of a species with captive animals does not necessarily reflect their full potentiality, as they may develop more slowly and less completely in such poor environments (DAVENPORT, 1979). Environment and training conditions also affect the human cognitive development (DASEN & HERON, 1981). Insofar as wild chimpanzees may have more developed cognitive abilities, the latter should preferably be studied in the field.

Why have Tai chimpanzees developed such high faculties in spatial representation? In human cross-cultural comparisons, differences were also found in spatial skills. It has been demonstrated that nomadic, hunting and gathering people develop spatial skills to a higher degree than do sedentary, agricultural people (DASEN, 1975; DASEN & HERON, 1981). We suggest that the exploitation of a particularly rich and patchy food source under conditions of poor visibility contributes to the high development of spatial capacities in the Tai chimpanzees.

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