

THE LOGIC OF SEARCHES IN YOUNG CHILDREN (*HOMO SAPIENS*) AND TUFTED CAPUCHIN MONKEYS (*CEBUS APELLA*)

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ABSTRACT: Nine young children and five tufted capuchin monkeys (*Cebus apella*) were tested on tasks involving a search for an object hidden within a set of plastic cups. As viewed, the sequences of displacements enabled subjects to eliminate some of the possible locations where the object lay hidden, thereby constraining the search space. Both species deployed principled modes of search, in contrast to a random selection strategy. However, no subject from either group proved able to fully constrain the search on the basis of all of the information conveyed over the full menu of tasks. The reasons for incomplete success are as yet unclear, however failures may be due as much to social limitations as to other forms of error. On that basis we conclude that new paradigms are necessary, designed specifically to evaluate competencies for socially based knowledge on the one hand and self-directed search on the other.

Memory and representation have a long history of exploration in research on both human and non-human species. Perhaps the oldest form is the delayed-response task pioneered by Hunter (1913), elaborated later with primates by Yerkes (1929), and culminating in the well-known versions introduced by Piaget (1955) as "object permanence" tasks. A common feature of these tests is the role they give the tester who first acts to capture the subject's attention by presenting an attractive object, such as a toy, or a piece of preferred food, before hiding it within containers or behind occluding screens which remain at all times within the test field. Either immediately afterwards, or following a delay, the subject is given an opportunity to seek hidden items. Persistence of search in the absence of direct perceptual information is the first indication of object memory or event permanence. However, beyond search oriented behaviour *per se*, the use of strategies may indicate a great deal about the subject's ability to

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constrain search to the relevant container alone, or, in the case of direct information concerning the precise location of the bait, to infer from its absence the most likely locations which remain to be explored.

Thus, infants in an object permanence task may search the first container visited by the experimenter, even though the item sought has been quite explicitly removed and placed in an alternative site by the experimenter, in full view of the subject (Bower, 1974; Diamond, 1985). In tasks, furthermore, where the act of hiding could not be perceived directly, but could be inferred only from the sequence of events in each task, Haake and Somerville (1985) found a strong developmental trend from 9 month to 18 month old infants in the way they co-ordinated temporal and spatial information. As these authors point out, the sequential nature of the hiding procedures required children "to attend to, remember and use information about the presence and absence of the object in the context of movements among potential hiding locations. In order to search logically, events occurring at different times and places in the displacement sequences had to be linked together to determine exactly where the object had been hidden" (page 185). Under these conditions, only the oldest children in the sample showed some consistent search pattern, for example, searching the last place the target object was seen, following a discovery that it was now "missing".

Tests of "pure" cognitive competencies are rare, if they exist at all, however. As in so many other such cases, the task used - or the conditions under which it is introduced - may itself be a factor in determining whether subjects will deploy exhaustive and relatively inefficient strategies or opt instead for controlled, efficient search. Certainly, Wellman, Somerville and Haake (1979) found considerable task-induced differences in strategies (which themselves change with age) of children aged from 2 to 6 years. Given doors in a cupboard to search versus areas of a playground, for example, children's responses indicated that "searches were more systematic and comprehensive in the cupboards than on the playground" (p. 541). The authors account for this difference by suggesting that searching "logically" makes greater demands on limited cognitive resources than other strategies, and that certain environments may be easy to search completely, as their cupboard task indicates. Certainly, this factor has been given further emphasis by the findings of Somerville and Capuani-Shumaker (1984). Their study, which forms the basis of the investigation reported in this paper, found that children from 3-5 years of age were able, under some circumstances at least, to constrain search on the basis of

watching a tester hide or find an object within a small test field containing 4 hiding places. Somerville and Capuani-Shumaker suggest, in fact, that making the children pay particular attention to the task (affording, as it does, a low cost solution even if the subject searches randomly) is a crucial factor in the subjects' success.

Whatever the role of the various factors involved, it is surely clear that the tasks described are of interest to the comparative psychologist, designed as they are both to evaluate the role of observer based and self-directed (discovery based) inference, in promoting search economy in a situation not unlike a foraging task (see McGonigle and Chalmers, 1992). Watching a conspecific visiting putative food sites, for example, may materially reduce the costs of search by an observer otherwise left to its own devices. Left to its own devices, on the other hand, the way an agent searches may also have a profound impact on the effort it expends when achieving its goal. Executing search in a random and unprincipled way, for example, could lead to costly reiterations, especially if the search space and the actual space to be searched is large (see Olton, 1982).

In summary, there would appear to be 2 main aspects to the search problem as described. The first is concerned with the extent to which an agent can improve efficiency of exploration when observing the behaviour of others. The second is concerned with the sorts of strategies which an agent, working on its own, will devise to keep search as efficient as possible. Common to both, are the cost functions which the agent must calculate in deciding if it is worth the effort of devising a strategy designed to make search efficient i.e. the "cost" of inference must be offset by the benefits of search economy. In this report, we seek primarily to determine whether socially transmitted search constraints are exploited by a non-human primate (*Cebus apella*). Since in the developmental studies just cited only percentages of children solving a particular condition of the experiment are reported and it is impossible to unambiguously characterise individual profiles among conditions, and since specific verbal instructions were used in the Somerville and Capuani-Shumaker study (1984) - we decided to first test some children of ages similar to those used in the Wellman et al. (1979) and Somerville & Capuani-Shumaker (1984) investigations. In doing so we modified the tasks where necessary, making them as similar as possible to those designed for the *Cebus apella* - who could not benefit, of course, from linguistically based instruction. In this way, we hoped to establish a robust template of performance in young children (when amalgamated in the research just cited) against which

the non-human primates could be compared.

EXPERIMENT 1: CHILDREN

METHOD

Subjects

The subjects were 9 children (5 boys and 4 girls) with a median age of 4 years and 11 months and a range of 4 years and 8 months to 5 years. All children attended the nursery of the Department of Psychology of the University of Edinburgh.

Apparatus

The testing apparatus was a specially modified WGTA, designed to enable the simultaneous presentation of a maximum of 5 stimuli (McGonigle & Chalmers, 1992). For the test described here, four white plastic cups were presented in line across a 18 x 50 cm tray. The objects to be hidden were a red and a blue rubber eraser which could be enclosed in the tester's hand and placed silently under a given cup, without giving any clues that it had been hidden there.

Procedure

Before each daily session, each child was taken from the departmental nursery to an adjacent testing room. The child sat in front of the tester, in full view of the cups, unless occluded by a screen. Each session lasted approximately 12 minutes. A camera positioned in front of the subject recorded his/her behaviour while looking at the hiding/finding procedure as well as while responding. A hiding and a finding task with relative warm-up trials (described below) were presented to each subject. Five subjects, selected at random (three boys and two girls), were presented first with the hiding task and the remaining four (two boys and two girls) were presented first with the finding task.

Hiding task. At the beginning of each test session, each child was told that the object was going to be hidden under a cup and that their task was to find it by lifting the cups. Before the administration of the hiding task, each testing session featured the presentation of warm-up

trials of two different types: type 1 and type 2. Type 1 warm-up trials were presented in each experimental session until a criterion of two consecutive correct searches, each performed within a latency of 5 sec., was achieved. In each of these trials, the tester's hand was moved under one cup and then removed and opened in order to show that the object was now absent. The subject was then allowed to search under the cups.

The rationale for the presentation of warm up trials type 1 was to assess whether the subjects were able to constrain their searches on the basis of the information provided by the hiding procedure. This was a necessary precondition for the presentation of a longer series of displacements such as that involved in the actual hiding and finding task. After the presentation of the type 1 warm-up trials, two type 2 warm-up trials were presented in each experimental session. In these trials the object was shown in an open hand at one end of the cups array. The hand was then closed and moved under all the four cups in succession, before being opened after the fourth cup to show that the object was now absent. The subject was then allowed to search under the cups. In one trial the hand moved from right to left and in the other trial from left to right.

The rationale for the presentation of the warm up trials type 2, was twofold. On the one hand it would have allowed an assessment of the ability of the subjects to understand that, after a series of displacements the object was still to be found within the array of cups (although in absence of any explicit information about the precise location of it under one particular cup). On the other hand, and because of the circumstance that the subject does not know the precise location of the object, the presentation of these trials would have allowed an evaluation of the way the subjects spontaneously perform an exhaustive search of a set of locations. In more detail it was interesting to evaluate whether, in absence of explicit information about the precise location of an object the subjects would have adopted a Systematic mode of search (i.e. a principled strategy such as searching always from one end to the other of the array), as opposed to an Asystematic mode of search (i.e. searching in a random order one location after the other).

The presentation of the warm-up trials was followed by the presentation of the experimental trials. Each daily session comprised a total of four experimental trials. Two trials conformed to a sequence of displacements referred to as the Object Present (OP) condition. The other two trials conformed to a sequence of displacements described as the Object Absent (OA) condition.

In the Object Present (OP) condition, the object was shown in a open hand at one end of the cups array, the hand was then closed and moved under all the four cups in succession before being opened after the fourth cup to show that the object was now absent. Between the second and the 3rd cup the hand was opened, to show that the object was still present in the hand. This critical event happening between hand's visit to the 3rd and 4th cup therefore allowed the inference that the object had been hidden under either the 3rd or the 4th cup visited. The alternation of the hand's direction of travel (right to left and left to right) assured that the 2 cups under which the object could be were not the same ones in the two trials administered in a daily testing session. A schema of the sequence of movements and events featured in this condition of the hiding task is shown in Figure 1, top left. The figure also illustrates the possible location of the object after a right to left (upper line) and a left to right (lower line) sequence of displacements.

For the Object Absent (OA) condition, the sequence of displacements was identical to that used for the OP condition, except for the fact that, when the hand was opened between the 2nd and 3rd cup, it was shown to be empty. As for the Object Present condition one sequence was left-to-right and the other right-to-left (see Fig. 1 bottom left, upper and lower line).

To summarise, in one experimental session, two trials of both Object Present and Object Absent conditions were administered to each subject. These included the experimenter moving his hand from left to right, and from right to left, for one trial of each condition, for a total of four trial types. The order of presentation of the four trials was selected at random for each daily session. Four daily testing sessions were administered and therefore a total of sixteen trials was collected for each subject.

Finding task. The verbal instruction given to the children at the beginning of each daily session was: "here are two objects which always hide together under the same cup; I will find one of them and you must find the other one". For each trial, a cardboard screen was interposed between tester and subject and the objects (now two, a red and a blue eraser) were hidden under one of the cups, out of the sight of the subject.

As for the hiding task, the administration of the finding task was preceded by the presentation of type 1 warm-up trials (until the achievement of the criterion) followed by two type 2 warm-up trials. These trials were similar to those used for the hiding task. The only

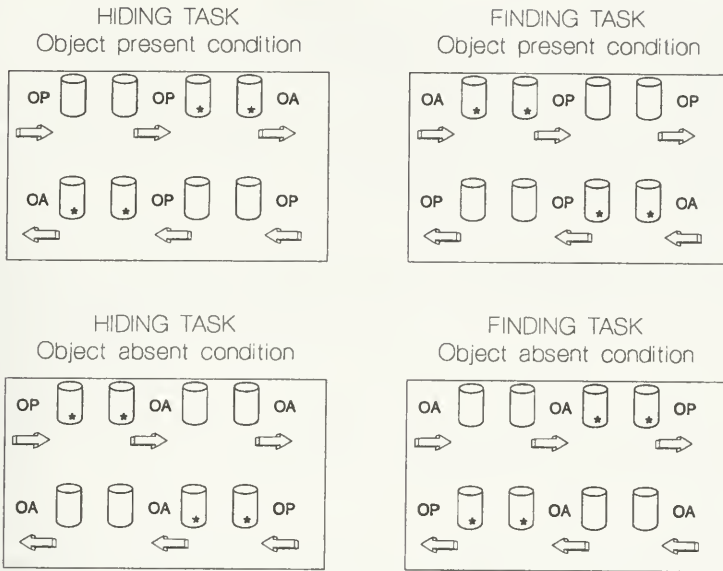


Figure 1. Schema of the Object Present (top) and Object Absent (bottom) featured in the hiding (left) and the finding (right) task. The events shown to the subjects at the beginning of the sequence of displacements, at the end of the sequence of displacements and the critical event shown after the hand had been passed under the 2nd cup and before it was passed under the 3rd cup are also depicted. OP (Object Present), indicates that the object is shown to be present in the tester's hand at that point of the sequence of displacements; OA (Object Absent), indicates that the tester's hand is shown to be empty at that point of the sequence of displacements. Arrows indicate the direction of travel of tester's hand. Asterisks indicate the possible location of the objects after the completion of the hiding/finding procedure.

difference was that the tester's hand was initially shown empty and later, after passing under the cup(s), revealed to contain one of the objects. The rationale for the presentation of both these types of warm-up trials was the same described above for the hiding task.

After the presentation of the warm-up trials four experimental trials were presented in each daily session. These experimental trials were analogous to those given in the hiding task, except that the objects were hidden, initially, out of sight of the subject. The informing event at the beginning of the sequence was now the absence of objects in the tester's hand. The intermediate event between the 2nd and the 3rd cup was either the presence of one of the objects in the tester's hand (OP

condition) or its absence (OA condition). A schema of the four different trials is shown in Fig. 1 (top right and bottom right).

The counterbalancing of the sequences of displacements followed the same schema as described for the hiding task. As for the hiding task, four daily testing sessions were presented and overall a total of 16 trials was collected for each subject.

Data recording. The tester recorded the location and order of occurrence of each search performed by the subject. A search was defined as the lifting of a cup. A scrutiny of the videotape records was performed in slow motion mode, in order to ensure that the data analysis was conducted only on those trials in which the subject watched without interruptions the whole hiding\finding procedure. In the event, none of the trials had to be eliminated.

Statistical analysis. All statistical analyses were based on the Binomial Test. In the Warm-up 1 trials the probability of occurrence of a successful (locating the object) search by chance was $p=.25$. In the hiding and the finding task the probability of performing an appropriate (selecting one of the two locations where the object could "logically" be hidden) first search by chance was $p=.50$, whereas that of locating the object (successful search) by chance in a second search (following an appropriate but unsuccessful first search) was $p=.33$.

RESULTS

Warm-up trials

In Type 1 of the hiding task, all the children understood the hiding procedure, satisfying the criterion of two consecutive correct responses with a latency of <5 sec. The group performance was of 87% correct responses ($p<.01$) and all subjects showed a proportion of correct responses above chance level ($p<.01$).

In the finding task, type 1, all children but one understood the procedure, reaching the criterion of two consecutive correct responses, each performed within 5 sec. The group performance was 45% correct responses ($p<.01$). The individual scores showed that 7 children out of 9 performed a significant ($p<.01$) proportion of correct responses.

In view of the similarity of the warm-up type 2 data from both hiding and finding tasks, these were combined in an analysis of the

different modes of search adopted by the subject to explore the array during type 2 trials. These have been divided into Systematic mode of search, i.e. the subjects explored the array from one end to the other (no fixed sequences other than end to end exploration were observed) and Asystematic mode of search, i.e. the search was performed at random. As should be expected by chance ($p=.25$), in the absence of any clue about where to search, the subjects located the object on their first choice only in the 21% of the trials. Subjects adopted a Systematic mode of search in the remaining 49% of the trials and an Asystematic one in the remaining 30% of the trials).

Hiding and finding task: Group performance

First searches. The percentages of appropriate first searches performed in the hiding and the finding task are shown in Table 1. From these it can be seen that appropriate first searches were performed above chance level. However, the most striking feature of the data is the selective effects of the sub-conditions within each task type. In the hiding task, the OP condition contributes almost uniquely to the overall success within this condition. In the finding task, by contrast, the OA condition is the most successful.

Second searches. As not all searches could be successful on the first choice even when controlled by a logical strategy, it was necessary to analyse second choice behaviour following putatively appropriate if unsuccessful first choices. Thus, second searches have been included in Table 1. In the case of both tasks, second choices (following an appropriate but unsuccessful first choice), are significantly in accordance with the choice of the appropriate location (i.e. locate the object). As Somerville and Capuani-Shumaker (1984) point out, however, it is necessary also to distinguish between endpoint based second choices and mid-position ones. This is because second choices which follow on from a choice of an end location and are adjacent to the endpoint, may be simply the result of object proximity *per se*, and not at all a reflection of the subject's understanding of the implication of the first choice. By contrast, when the first choice is performed at an appropriate inner location, a second response performed on the basis of mere proximity would locate the object only in the 50% of the occasions. For this reason, in Table 1, second searches have been divided into those that followed first searches at inner and end points of the array. It can be seen that subjects were significantly searching in the appropriate location in both tasks, even when only second searches following a first search at an inner point are considered.

Table 1. Distribution of children's searches in the hiding and finding tasks. OP, Percentages of total number of appropriate first searches in the Object Present condition; OA, appropriate first searches in the Object Absent condition; Successful second searches, occasions where the subjects locate the object following an appropriate although unsuccessful first search in which the Object had not been found; FI, The relative contribution to second search success of searches performed following an inner point based first search; FE, searches performed following an endpoint based first search. *, $p < .05$; **, $p < .01$.

| Task | Appropriate first searches (%) | | | First search outcome (%) | | Successful second searches (%) | | |
|---------|--------------------------------|------|------|--------------------------|------------------|--------------------------------|------|-------|
| | All | OP | OA | Object found | Object not found | All | FI | FE |
| Hiding | 74** | 89** | 58 | 66 | 34 | 88 | 79** | 100** |
| Finding | 68* | 61 | 75** | 69 | 31 | 75** | 67** | 84** |

Hiding and finding task: Individual performances

Given the asymmetrical distribution of appropriate first searches between the two sub-conditions of the hiding and the finding task and between the two tasks themselves, it is particularly interesting to consider how each child handled the various situations. A probability of 0.05 or less obtained on the basis of a binomial test conducted on the percentages of appropriate first searches in each of the conditions of both tasks was considered as evidence of success for a particular subject in a particular condition. Only one child succeeded in both conditions of the hiding task and one in both conditions of the finding task. The behaviour of the remaining subjects is highly consistent with the group results: performing appropriate searches mostly in the easiest condition of each task. No subject searched in the appropriate location in both tasks. Combining the percentages of appropriate first searches performed by each subject in the two conditions of each task, it emerges that three children searched appropriately in the hiding task and two in the finding task.

Identification of strategic behaviours

Up to this point, we have evaluated how successful our subjects were in selecting the two appropriate locations on the basis of the inferences that could be drawn from the observed sequences of displacements. However, it is important to take as much of the behaviour into account as possible. In fact, some strategies (which do not lead directly to "significant" correct performance) could possibly be identified by an analysis of the whole data base which includes both appropriate and inappropriate responses. The presence of strategies would indicate that searches, even when not appropriate, are not performed at random. In order to evaluate this possibility, we subjected the choice data to a further analysis based on a taxonomy of other strategic possibilities proposed by Somerville and Capuani-Shumaker (1984) and described as follows.

For each subject, a significant difference ($p < .05$) from the value expected if first choices oscillated randomly between two possible pairs of locations (Binomial Test, two tailed) was considered as evidence for conformity to a strategy.

One strategy would lead to a bias towards the selection of either the first two or the last two locations visited by the tester's hand and can be designated as temporal. Two children conformed to a temporal strategy in the hiding task and one in the finding task, selecting consistently the last two locations.

Another strategy could be a simple position bias toward the two left hand side (LHS) or the two right hand side (RHS) locations. In the hiding task, one subject conformed to this spatial strategy selecting consistently the right hand side locations, while in the finding task such a strategy was used by two subjects: one selected the right hand side locations and the other one chose the left hand side locations. Overall, only two subjects did not appear to use any strategy at all in the hiding task and three in the finding task.

To examine strategic consistency, the relationships between the strategic behaviour of each subject on each of the tasks, was evaluated. There was little evidence that strategies deployed in one task were used by the same subject in the other. For example, two of the three subjects that showed evidence for a "logical" strategy in the hiding task did not conform to any strategy in the finding task and the third, in the finding task, always chose the last cup visited by the tester. The two children that selected the appropriate locations in the finding task, always selected the same location or did not using any strategy at all, when presented with the hiding task. Ko searched according to a temporal

strategy (Last 2) in the hiding task and according to a spatial strategy in the finding task (RHS). Br did not use any strategy in the hiding task but conformed to a spatial strategy in the finding task (LHS). Gi did not conform to any strategy in both the tasks and An, who was tested in the hiding task only, searched according to a spatial strategy (Last 2).

DISCUSSION

Children in this study are not found fully competent to use observationally based constraints on choice when both hiding and finding tasks are taken as criterial. No child succeeded in both tasks. Instead, success was partial, emerging primarily in the Present Condition of the hiding task, and the Absent Condition of the finding task. A similar trend has been found by Somerville and Capuani-Shumaker (1984). This result, combined with our evidence that the behaviour, even when inappropriate, was essentially non-random indicates that the children's failure was not merely the result of boredom, or of inappropriate testing procedures. Overall the picture which emerges from the child data appears a heterogeneous one. Some children seem to perform observationally constrained searches in one or the other of the two tasks. However, no one subject conforms fully to the criteria set to determine "logical" search in both tasks and for both conditions of each task. There are, nevertheless, many consistent features of performance which suggest that data are not idiosyncratically generated by each subject, nor the product of poor test conditions or procedures. Instead, we would argue that, this suggests that children of the age we tested are only partially competent at dealing with some of the implications of events which they perceive directly, even in a situation as (ostensibly) simple as the one we describe. There is evidence of a difficulty in dealing with information implied by the absence of an object or event. In addition, the requirement to couple simple background knowledge (conveyed linguistically) with the interpretation of directly perceived events is far from optimal. These lacunae aside, however, there is also evidence of a gradient of constraint on search and object choice which these subjects may exploit on the basis of the observations of the behaviour of a third party. Would this also be true of the behaviour of a non-human primate, the *Cebus apella*? We addressed this question in our next study.

EXPERIMENT 2: MONKEY - PHASE A

The experiment with the monkeys comprised two different phases, phase A and phase B. A precondition for the administration of the hiding and finding tasks which feature complex sequences of displacements is that the subject will search at all, under conditions where the size of the set to be searched is four items and sometimes under delays of at least 3 sec. Phase A was essentially an attempt to give the monkeys experience of searching under these conditions. Phase B featured the presentation of the hiding and the finding task to the monkeys.

METHOD

Subjects

The subjects were two adult males (Al and Ch) and three adult females (Lu, Ki and Ol) wild born tufted capuchin monkeys (*Cebus apella*). They were housed in a colony compound within the Laboratory for Cognitive Neuroscience of the University of Edinburgh. At the time of the experiments the colony was composed of two adult males and five adult females. The enclosure was equipped with perches, water sources, tree branches and hangers suspended from the ceiling in order to provide locomotor opportunities. A layer of wood shavings covered the floor. To encourage foraging behaviour, a mixture of seeds was dispersed into the wood shavings on daily basis. Water was available *ad libitum*. The monkeys were transferred in individual cages for the testing sessions that took place in the morning. Reward was based on highly preferred food (grapes). All the monkeys were experimentally naive and had just terminated a period of quarantine of 6 months.

Apparatus

The testing apparatus was analogous to the modified version of WGTA, used for the children in experiment 1. The cups used to cover the bait were the same sort of white cups used for the children in experiment 1. The bait was a white grape that could be enclosed in the tester's hand and placed silently under the cups without giving the subject any auditory or visual clue. Up to 5 polystyrene white cups were used to cover the objects.

Procedure

Essentially this phase of the experiment was motivated to enable the monkeys to cope with up to 5 cups per trial and a delay interposed between hiding and retrieval. To achieve this, 3 conditions were presented to the monkeys in the following order: a visible baiting condition, comprising 5 phases featuring the presentation of 1, 2, 3, 4 and 5 cups, respectively; a control condition; and a delay condition. The data recording was as described for Experiment 1.

Visible baiting condition. A cup was baited while the subject was looking. Starting from trials in which only one cup was presented on the tray, the number of cups was increased until a linear array of five cups was presented. For each trial, the cup to be baited was randomly chosen within the array. When the subject reached a criterion of five consecutive correct responses, each performed within a latency of five seconds, one more cup was added to the previous array. On reaching this criterion for the five cups array, subjects were overtrained for several sessions to ensure a stable performance before the administration of the next stage.

Control condition. An array of 5 cups was presented. The procedure consisted in moving a second cup simultaneously with the displacement of the bait. Thus the mere movement of a cup could not be taken as a sign indicating which cup was being baited. The second cup to be moved was randomly selected for each trial.

Delay condition. The task featured the presentation of a 5 cups array. First, a 3 sec. delay was introduced between the displacement and the retrieval of the bait, subsequently increased to 5 sec., for those subjects which did not show a noticeable performance decrement.

Statistical analysis

A Binomial Test was performed on data obtained from the extensive testing with the 5 cups array, the Visible Baiting Condition, the Control Condition and the Delay Condition. The probability of occurrence of a successful search by chance was $p=.20$.

RESULTS

Visible baiting condition. All subjects immediately searched for the bait when it was hidden under the only cup presented. In the phases

featuring the presentation of 2, 3, 4 and 5 cups, the averaged numbers of trials to criterion were 24.6 ($sd=20.9$), 8.6 ($sd=4.1$), 8.8 ($sd=4.1$), 6.8 ($sd=2.2$), respectively. The highest number of trials to criterion was found (for four subjects out of five) in the condition where two cups were presented. For one subject (Lu) the highest number of trials to criterion was found when it was presented with 4 cups. The averaged percentage of correct choices in the extensive testing with the five cups array was 92.8% ($sd=4.4$, $p<.01$). The overall percentage of correct choices made by each subject was also highly significant (Al=97%, $p<.01$; Ch=91% $p<.01$; KI=94% $p<.01$; Lu=96% $p<.01$; O=86% $p<.01$).

Control condition. The mean percentage of correct choice in the control condition was 90% ($sd=9.5$), $p<.01$). All the subjects showed a highly significant percentage of correct responses. Only one subject (Ki) showed, in this condition, a percentage of correct responses lower than that shown in the previous test phase (visible baiting condition with five cups).

Delay condition. The interposition of a 3 sec. delay between hiding and retrieval did not disrupt the performance of 4 subjects out of 5. The percentages of correct choices made by Ol (90%), Ch (94%), Lu (80%) and Al (92%) were all highly significant, while that performed by Ki (32%) did not reach statistical significance. When the delay was increased from 3 to 5 sec. most subjects expressed distress by either staying apathetically in a corner of the cage without paying attention to the testing procedure or by moving frantically and occasionally shaking the apparatus. We were thus obliged to terminate the administration of this condition. However, the two subjects (Ol and Ch) that received enough trials to compare their percentages of correct responses (Ol=68% and Ch=73%) to chance, searched correctly ($p<.01$) even when a 5 sec. delay was interposed between hiding and retrieval.

DISCUSSION

Visible baiting condition. Results obtained from this first set of tests show that all subjects were committed to search for an object they had seen disappear under a cup. The incentive to search for an object, now out of sight, was apparent even from the first condition in which only one cup was presented. However, in a single cup condition, the action of lifting it might be expression only of a manipulative disposition on the part of the subject, and not necessarily motivated by

the bait *per se*. The fact that the subjects chose the baited cup only, under multiple cup conditions, indicates to the contrary. Nevertheless, this selective response in the presence of multiple hiding places was acquired in the course of testing and was not expressed spontaneously. It would seem, therefore, that there is already a disposition to use a self-directed mode of search. When one cup is presented, this mode is sufficient for immediate success; where there are alternatives, however, it is not. Informed by failure, however, the monkey's search, once constrained through observation of the tester, appears unaffected by the addition of further distractors (up to five cups presented in a linear array).

Control condition. Results obtained from the control condition show that subjects were not using cup movement alone as a unique clue to location of reward. Instead, the serial displacement procedure alone was taken as the informing event.

Delay condition. An evaluation of the delay that subjects were able to tolerate was necessary before Phase B of Experiment 2; that required an attentional phase of approximately 2-3 sec., if the tasks were to be administered successfully. As four of the subjects proved able to cope with an interval of at least 3 sec. a necessary precondition for Phase B was satisfied.

EXPERIMENT 3: MONKEYS - PHASE B

METHOD

Subjects

The four monkeys (Al, Ch, Lu, and Ol) that proved able to tolerate at least a 3 sec. delay in the preceding stage were used as subjects in this phase.

Apparatus

The testing apparatus was the WGTA used for Phase A. Four cups, identical to those used in Experiment 1 and in Phase A of experiment 2, served to cover the baits. The baits were black and white grapes.

Procedure

The administration of the Warm-up trials and the experimental

trials of the hiding and finding task to the monkeys was as described for children in Experiment 1. Two monkeys (Ch and Lu) were first presented with the hiding task and the remaining two (Al and Ol) began with the finding task.

Warm up. The warm up trials presented to the monkeys, both for the hiding and the finding task, were identical to those presented to the children and described for Experiment 1.

The procedure adopted with the monkeys in the hiding and the finding task followed the same schema featured in Figure 2, with the following minor modifications.

Hiding task. At the beginning of each daily session subjects were motivated with five trials in which the bait was hidden under a cup and the subject had to retrieve it. This was followed by 4 experimental trials.

Finding task. Before the administration of the finding task, it was necessary to convey, non linguistically to the subjects the crucial information that two baits were always hidden together under the same cup. This was attempted by administering a task identical to the visible baiting condition described above, except for the fact that two baits (a black and a white grape) were hidden together under one of the cups. This was followed by 4 experimental trials per session using the procedures as described for children in Experiment 1.

Statistical Analysis

The statistical data analysis followed the schema described for Experiment 1.

RESULTS

Warm-up Trials

Type 1 for the hiding task. The group performance averaged 84% correct responses ($p < .01$). Three of the monkeys (Ch, Lu and Ol) were individually correct above chance level ($p < .01$, Binomial test, one tailed) indicating that the hiding procedure was understood. The fourth subject (Al), that was presented first with the finding task, became so stressed during the presentation of the finding task that the experiment had to be terminated before the presentation of the warm up trials for the hiding task.

Type 1 for the finding task. The monkeys were given on average

25 visible baiting trials with two baits (range=21-30) before the administration of two Warm-up 1 trials. The averaged percentage of correct searches was 95.2% (range=90%-100%). The percentage of correct searches of all the subjects was above chance level ($p < .01$, Binomial test with a chance probability of occurrence of a correct search =.25). The combined percentage of correct searches for the two monkeys (AI and OI) presented with the Warm-up 1 trials was 73% ($p < .01$) and also significantly above chance level ($p < .01$) considered as individuals. The other two monkeys stopped searching after a few failures and the administration of this task was terminated.

Type 2. As for the child sample, preliminary data analyses showed no major differences between the results obtained from the warm-up 2 trials for the hiding task and the Warm-up 2 trials for the finding task. Therefore, the results from the two tasks have been combined. As with children, monkeys were at chance when locating the object, on their first attempt (22% of the trials). They adopted a Systematic mode of search more often than an Asystematic one, although the percentage of occasions in which the subjects were Asystematic is considerable. In fact, 36 searches (50% of the total number of searches) were performed in a Systematic way, while 20 (28%) were Asystematic.

Hiding and finding task

Group performance. Table 2 shows the percentages of appropriate first searches performed by the monkeys the hiding and finding tasks. It can be seen that the percentage of appropriate first searches was above chance level in the hiding task but was not significant in the finding task. This taken together with a selective effect of sub-conditions within each task type, analogous to that found for the children, leads to a major difference between tasks.

In the hiding task the monkeys identified the location of the object after a first appropriate choice, as shown in Table 2. Successful second searches were above chance level either when following a first appropriate choice at an end point or at an inner point of the array. As shown in table 2, in the finding task, the combined percentage of successful second searches for the two conditions is again above chance level; when analysed according to first search location, second successful searches following an end point first choice are highly significant; those that followed a first choice to an inner location, whilst successful in all cases (3) are too few to yield to statistical test.

Table 2. Distribution of monkey's searches in the hiding and finding tasks. Abbreviations as in Table 1.

| Task | Appropriate first searches (%) | | | First search outcome (%) | | Successful second searches (%) | | |
|---------|--------------------------------|------|------|--------------------------|------------------|--------------------------------|------|-------|
| | All | OP | OA | Object found | Object not found | All | FI | FE |
| Hiding | 87** | 93** | 81** | 54 | 46 | 94** | 88** | 100** |
| Finding | 53 | 41 | 65 | 73 | 27 | 100** | 100 | 100** |

Individual Performances. As for children, given the asymmetrical distribution of first choices across tasks and conditions, the data were analysed on an individual basis.

In the hiding task, three subjects searched appropriately above chance level in the Object Present condition and two in the Object Absent condition. Neither of the subjects presented with the finding task performed above chance in either the OP nor in the OA condition. Combining the results obtained from the two conditions of each of the tasks secures the conclusion that all three monkeys tested in the hiding task appropriately performed first searches above chance level. In contrast, the two that were presented with the finding task both failed. The main differences are therefore between tasks, not conditions. What seems clear is that the finding procedure is itself difficult to understand. In fact, the subject that was presented with the finding task first never solved it, and expressed distress by moving frantically in the cage and occasionally shaking the apparatus, therefore we were forced to discontinue testing. Moreover, the two subjects that proved successful on the hiding task, failed the warm-up trials of the finding task. After a few unsuccessful attempts they eventually ceased search for the hidden bait.

Identification of strategic behaviours

We have already seen that monkeys behaviour was "logical" while performing the hiding task. However, when presented with the finding task they used a spatial strategy. In particular each subject in the finding task chose always the same end location on the same side (one subject chose left, the other right).

DISCUSSION

Monkeys in this experiment appear able to use the behaviour of a third party in the hiding but not the finding task. This indicates that even in this small task domain, the cost functions are appropriate to the induction of an observationally based strategy. Special, desirable food may well be a strong factor, energising the subject in circumstances where children may need strong social facilitation to maintain attention and devise more complex solutions perhaps than the task may otherwise warrant.

However, where the tester acts as finder, the monkeys fail. While this may indeed be a direct result of a failure to appreciate a "finding" role, as described by Fischer & Jennings (1981) and Berthenthal & Fischer (1983), the fact that the performance of children in our own study was also relatively poor (as indeed was the performance of subjects in the Somerville and Capuani-Schumaker study) indicates that the task is difficult to comprehend. One index of this is given by the number of verbal prompts required in the Somerville and Capuani-Shumaker study (1984). Task communication apart, however, the subject must link some background knowledge with the perception of object displacement i.e. it is crucial that the subject interprets the object event at the end of the finding sequence in the light of the background knowledge that the objects are always together. The most likely reason for the failures in the finding task, therefore, would thus appear to be based on a failure to understand that both items are "always together". If so, there is no reason to believe that a common strategy will operate in the variety of conditions to which the subject is exposed in this experiment. The various task requirements, in fact, scale according to an abductive inference¹ analysis which indicate that each of the conditions of the experiment varies in the demands it makes on the subject. On that basis, we would expect the data to assort according to the hierarchy of difficulty suggested by the analysis. For the same reasons, we would not expect to find any consistency of "strategy" across tasks and conditions, nor do we.

¹ If, as Peirce (1955) suggests (see Luger and Stern, 1990), the observation and identification of facts is conditioned by a background of expectations, than a signal absent condition will frequently demand more of the subject by way of interpretation, than the signal or event on which that interpretation is based. So the partiality of the success, whilst initially paradoxical when the cross over effects due to the object presence/absence as a function of tasks are considered, is quite rational when considered from this perspective.

GENERAL DISCUSSION

A first implication of our results is that capuchins are able, at least under some testing conditions (e.g. the hiding task), to successfully deal with a series of invisible displacements. These results somehow complement studies conducted within the piagetian framework and support results showing a capuchin monkey solving a test for stage 6 of object permanence (Schino, Spinozzi & Berlinguer, 1990) in contrast to another study where all the subjects tested failed (Natale & Antinucci, 1989). However, the fact that also 4 and half year old children failed to solve all conditions of the tasks suggests that the requisite of object permanence was only a component of the skills required for success in the tasks employed here. Although our results provide some information about the controversial issue of the achievement of stage 6 of object permanence in capuchins we would invite caution in reading our results in that light. The tasks we describe in this paper were not specifically designed to evaluate piagetian stage 6 of object permanence in capuchin monkeys. Moreover, it is a long time since it has been indicated that the concept of object permanence might itself conceal a compound of different sub-competencies (Bower, 1974).

The tasks we used have been designed to evaluate the strategies subjects may use when searching for unseen objects. Ostensibly they are about the ways in which the agent constrains search both on the basis of information received and (as in the finding task) on the basis of prior information, needed to interpret the events under the subject's interrogation. The results vary both across and within species. In the former case, the variation seems to have something to do with the type of task used, the effort of searching and the cost functions attaching to that search (see Wellman et al., 1979). In addition, there may well be social factors at work. The (social) costs of mistake in situations where the adult tested has carefully coached the child in the rubric of the test may well contribute to the performance recorded by Somerville and Capuani-Schumaker (1984). Whilst these are unlikely to apply in the case of the monkey, failure to retrieve highly preferred food, albeit in situations where search is otherwise un-costly may dispose the *Cebus* in our experiments to pay particularly good attention to the behaviour of the tester. A further social factor is the sort of role assigned the tester, as hider or as finder, as collaborator or as deceiver. These latter factors may all play a part, particularly in encounters with conspecifics. For these reasons, it may be best to specialise and develop experimental paradigms which target a cohort of closely related issues. For example, the social aspects of the encounters are already represented in

experiments on social inference and imitation. In non-human primates, recent studies by Visalberghi & Fragaszy (1990) and by Povinelli, Parks and Novak (1991) are examples of controlled assessments of the use of socially derived information by non-human subjects.

A complementary but separable line of inquiry is one concerned with self-directed search under conditions which do not presume socially based observational competencies as a precondition for its operation. Here the tasks used in the study we describe are flawed, when considered from this perspective alone. One major reason for this is that each manual interrogation of an object displaces it from its test position, thus leaving a visible trace of a visit. Under these circumstances, it would be a very foolish subject who attempted to reiterate visits to previously interrogated locations. Yet a measure of reiteration is essential if we are properly to evaluate the extent to which subjects can keep track of choices made serially over time.

Recently, serial-order search tasks for human and non-human primates have been developed using paradigms and procedures designed to evaluate size seriation skills (McGonigle, 1987; Chalmers and McGonigle, 1997). These are intended primarily to evaluate self-directed search strategies without reference to a third party. Recently, we have reason to believe that the non-human primate, *Cebus apella* can devise its own strategies in an exhaustive search task, becoming more economical by paying attention to the spatial organisation of items in the search space (McGonigle & Chalmers, 1992, 1996; De Lillo, Visalberghi & Aversano, 1996). As a consequence of this, we will shortly report the results of new paradigms based on computer-interactive touch screen technology which enables the experimenter to display a wide range of items through which the subject must search (for an outline of the paradigms and preliminary results see Terrace & McGonigle, 1994; Visalberghi & De Lillo, 1995; De Lillo, 1997; and McGonigle & Chalmers, 1998). However, unlike our present procedures, each touch leaves no lasting trace of a touch, leaves the subject to discover its own best (most efficient) route through the search space, and is sufficiently motivating to keep the subject working for protracted periods thus enabling a comprehensive in-depth analysis of each case. Apparatus and procedures which satisfy these requirements have also been developed for the study of search skills in environments of larger scale than a computer monitor and used to test capuchin monkeys faced with a variety of different spatial configurations of baited sites (Visalberghi & De Lillo, 1995).

In short, the partitioning of research into issues concerning social

regulatory factors in cognition on the one hand, and self-regulatory ones on the other, offers, we believe, the best prospect for the study of information organisation and management by primates for some time to come.

REFERENCES

- Berthenthal, B. I., & Fischer, K. W. (1983). The development of representation in search: A social-cognitive analysis. *Child Development*, *54*, 846-857.
- Bower, T.G.R. (1974). *Development in infancy*. San Francisco. W.H. Freeman and Company.
- Chalmers, M., & McGonigle, B.O. (1997). Capturing dynamic structuralism in the laboratory. In L. Smith (Ed.), *Piaget, Vygotsky and Beyond*. Routledge, London.
- De Lillo, C. (1995). Strategic search behaviour in monkeys. Abstract in: E. Alleva, A. Fasolo, H.P. Lipp, L. Nadel & L. Ricceri (Eds.), *Behavioral brain research in naturalistic and semi-naturalistic settings: Possibilities and perspectives*. NATO ASI Series, Series D: Behavioral and Social Sciences, Dordrecht, Kluwer Press.
- De Lillo, C. (1997). The serial organisation of behaviour by non-human primates: an evaluation of experimental paradigms. *Behavioural Brain Research*, *81*, 1-17.
- De Lillo, C., Visalberghi, E., & Aversano, M. (1996). The organisation of exhaustive searches in a "patchy space by capuchin monkeys (*Cebus apella*). *Journal of Comparative Psychology*, *111*, 82-90.
- Diamond, A. (1985). Development of the ability of use recall to guide action, as indicated by infants performance on AB. *Child Development*, *56*, 868-883.
- Fischer, K. W., & Jennings, S. (1981). The emergence of representation in search: understanding the hider as an independent agent. *Developmental Review*, *1*, 18-30.
- Haake, R.J., & Somerville, S.C. (1985). Development of logical search skills in infancy. *Developmental Psychology*, *21*, 176-186.
- Hunter, W.S. (1913). The delayed reaction in animals and children. *Behavior Monographs*, *2*, Vol. 6, 1-86.
- Luger, G.F., & Stern, C. (1990). *Expert Systems and the abductive circle*. The University of New Mexico. Technical Report No. CS90-17.
- McGonigle, B.O. (1987). Non verbal thinking by animals? *Nature*, *325*, 110-112.
- McGonigle, B.O., & Chalmers, M. (1992). Monkeys are Rational. *The Quarterly Journal of Experimental Psychology. Section B. Comparative and Physiological Psychology*. *45b*, 189-228.
- McGonigle, B.O., & Chalmers, M. (1996). The ontology of order. In L. Smith (Ed.), *Critical readings on Piaget*. Routledge, London.
- McGonigle, B.O., & Chalmers, M. (1998). Rationality as optimized cognitive self-regulation. In M. Oaksford & N. Chatex (Eds.), *Rational Models of Cognition*. Oxford University Press, in press.
- Natale, F., & Antinucci, F. (1989). Stage 6 object concept and representation. In F. Antinucci (Ed.), *Cognitive structure and development in non-human primates*. Lawrence Erlbaum Associates, Hillsdale New Jersey.
- Olton, S.O. (1982). Spatially organized behaviors in animals: Behavioral and

- neurological studies. In M. Potegal (Ed.), *Spatial abilities. Development and physiological foundations* (pp. 335-360). New York: Academic Press.
- Peirce, C.S. (1943). *The Philosophical Writings of Peirce*. New York: Dover Publications.
- Piaget, J. (1955). *The Construction of Reality in the Child*. London: Routledge and Kegan Paul.
- Povinelli, D.J., Parks, K.A., & Novak, M.A. (1991). Do rhesus monkeys (*Macaca mulatta*) attribute knowledge and ignorance to others? *Journal of Comparative Psychology*, *105*, 318-325.
- Schino, G., Spinozzi, G., & Berlinguer, L. (1990). Objects concept and mental representation in *Cebus apella* and *Macaca fascicularis*. *Primates*, *31*, 537-544.
- Somerville, S.C., & Capuani-Shumaker, A. (1984). Logical searches of young children in hiding and finding tasks. *British Journal of Developmental Psychology*, *2*, 315-328.
- Visalberghi, E., & Fragatszy, D. (1990). Do monkeys ape? In S. Parker & K. Gibson (Eds.), *"Language" and intelligence in monkeys and apes* (pp. 247-273). New York: Cambridge University Press.
- Visalberghi, E., & De Lillo, C. (1995). Understanding primates behaviour: A cooperative effort of field and laboratory research. In: E. Alleva, A. Fasolo, H.P. Lipp, L. Nadel & L. Ricceri (Eds.), *Behavioral Brain Research in Naturalistic and Semi-naturalistic settings: Possibilities and Perspectives*, NATO ASI Series, Series D: Behavioral and Social Sciences. Dordrecht, Kluwer Press.
- Wellman, H.M., Somerville, S.C., & Haake, R.J. (1979). Development of search procedures in real-life spatial environments. *Developmental Psychology*, *15*, 530-542.
- Yerkes, R.M., & Yerkes, A.W. (1929). *The great apes: a study of anthropoid life*. New Haven: Yale University.