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DIPLOMARBEIT

Titel der Diplomarbeit

„Touch-screen experiments:

Common Marmosets (*Callithrix jacchus*) can discriminate between positive and negative stimuli, but can they also reason by exclusion?“

Verfasserin

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2. Abstract

Common Marmosets (*Callithrix jacchus*) are small New World monkeys that live in a cooperative (social) breeding system. Several studies have previously investigated social learning mechanisms (e.g. social facilitation, imitation) in Common Marmosets (Bugnyar and Huber 1997, Voelkl and Huber 2000; 2007). However, they were not designed to explicitly examine the capacity to think logically, especially to infer reasoning by exclusion. To test the marmoset's level of cognitive behavior, for example, recognition and understanding of a relationship between two components, I used 8 Common Marmoset individuals in a computer-controlled two-choice procedure. The animals performed on a touch-sensitive screen and had to learn several pairs of images (S+/S-) whereby positive and negative feedback was given for the choice of each stimulus, respectively. In *Test 1-Choosing by exclusion*, the familiar negative stimuli (S-) were presented simultaneously with novel ones (S´). By excluding the negative class membership, animals should be able to replace the missing S+ with the novel stimulus (S´). Animals who significantly chose the novel stimulus over S- , also participated in a second test, which assessed their ability for inferential reasoning by exclusion. The previously used novel stimuli (S´) were presented simultaneously with undefined new stimuli (S´´). Animals, which employed reasoning by exclusion in *Test 1-Choosing by exclusion*, were expected to continue to recognize the S´ as positive in the *Test 2-Learning by exclusion*. However, it was not clear if the marmosets defined the novel stimuli as positive stimuli. Thus *Training* trials were rewarded and *Test* trials were not, i.e., the monkeys may have expected a solution which received a reward during the *Test* trials. It seemed as if they had difficulties to apply the desired method in the *Tests*. They preferred the trial and error method during the *Test* trials and seemed to continue to use this method which they learned from the *Training*.

Keywords: Common Marmoset, discrimination, novel stimulus, reasoning by exclusion, touch-sensitive screen

3. Zusammenfassung

Das Ziel dieser Studie war es die kognitiven Fähigkeiten von Weißbüscheläffchen (Callithrix jacchus) im Rahmen von „Touch-screen-Experimenten“, zu testen. Die verwendeten acht Versuchstiere waren mit Computer-kontrollierten Aufgaben noch nicht vertraut. Die Weißbüscheläffchen mussten lernen verschiedene Stimuli (S+/S-) am Bildschirm zu diskriminieren. Damit wollte ich untersuchen, ob sie Assoziationen zwischen positiven und negativen Bildern im Zusammenhang mit Belohnung verknüpfen können und ob sie die Fähigkeit besitzen, logisch nach Ausschlussprinzip zu handeln. Außerdem wurde das Lernverhalten der unterschiedlichen Geschlechter und Altersgruppen verglichen.

Für das Training wurden S+ und S- immer gemeinsam am Computerbildschirm präsentiert. S+ wurde als positiver Stimulus belohnt und S- blieb als negativer Stimulus immer unbelohnt. Außerdem hatten die Tiere bei Fehlversuchen die Möglichkeit, sich selbst zu korrigieren (Versuchs-Irrtums-Methode). Alle, bis auf ein Tier, zeigten keine Schwierigkeiten die unterschiedlichen Trainingsbilder zu erlernen. Es wurden auch keine signifikanten Unterschiede in Bezug auf Geschlecht oder Alter, gefunden. Nach dem Erlernen der unterschiedlichen Stimuli wurden die Tiere mit Hilfe von zwei Tests auf logisches Handeln nach Ausschlussprinzip getestet. Für den ersten Test (Test 1-Wahl nach Ausschlussverfahren) mussten die Versuchstiere acht Sessions durchlaufen. Jede Session bestand aus 28 Training- (S+/S-) und 4 Test-trials (S´/S-). Die Testbilder (S´) waren neue, noch unbekannte Stimuli. Aufgrund ihrer gelernten Erfahrung, sollten die Tiere nun den negativen, bekannten Stimulus, ausschließen und den fehlenden positiven (S+) durch den neuen Stimulus (S´) ersetzen.

Im zweiten Test (Test 2-Lernen nach Ausschlussverfahren) wurden zusätzlich zu den S´, wieder neue, bis dato, noch unbekannte, Stimuli (S´´) gezeigt. Die Test-trials bestanden nun aus einer Kombination von S´- und S´´- Paaren. Tiere, die im ersten Test S´ signifikant bevorzugten, sollten diesen auch im zweiten Test bevorzugen, da der Stimulus von ihnen bereits als positiv definiert wurde. Jene Tiere, die in beiden Tests S´ signifikant wählten, könnten logisch nach Ausschlussprinzip gehandelt haben.

Der Grund für die Durchführung von Test 2 war, dass neben dem Handeln nach Ausschlussprinzip auch noch alternative Strategien hinter einem signifikanten S´-Ergebnis stehen können, wie zum Beispiel neophiles Verhalten. Neophilie bezeichnet die Vorliebe für neue Dinge. Hätten meine Versuchstiere aufgrund von Neophilie gehandelt, hätten sie auch im zweiten Test den neuen S´´- Stimulus

signifikant wählen müssen, weil S´ zu diesem Zeitpunkt bekannter als S´´ war und die Tiere es vorgezogen hätten den neuen Stimulus auszuprobieren. Damit wäre die These, dass Tiere nach Ausschlussprinzip handeln, wiederlegt. Der gegenteilige Mechanismus zu Neophilie ist Neophobie. Auch diese Strategie sollte untersucht werden. Eine abwehrende Haltung gegen alles Neue bezeichnet neophobes Verhalten. Die Tiere, die diese Strategie angewendet hätten, würden in Test 1 wie auch in Test 2 die neuen Stimuli signifikant vermeiden, da sie ja eine Scheu vor unbekannten Dingen hätten.

Die Ergebnisse meiner Studie erbrachten keinen Beweis, dass die Versuchstiere logisch nach Ausschlussprinzip gehandelt hätten. Neophiles und neophobes Verhalten kann aber, mit Ausnahme von einem Tier, als Grund für die Ergebnisse ausgeschlossen werden. Daher muss ich sagen, dass hinter den negativen Resultaten wahrscheinlich ein anderes Problem stand.

Es scheint, als habe die unbelohnte Testsituation einen negativen Einfluss auf das spontane Verhalten der Tiere gehabt. Während den Test-trials (S´/S-) wirkten die Tiere irritiert und suchten nach einer Problemlösung, welche für sie nur als richtig schien, wenn sie dafür auch Belohnung erhalten würden. Bei korrekter Antwort in S+/S- -trials (Training-trials) bekamen die Tiere Belohnung, jedoch in S´/S- -trials (Test-trials) blieb die Belohnung aus, unabhängig davon welcher der beiden Stimuli ausgewählt wurde. Obwohl die Tiere in den Training-trials S- erfolgreich ausschlossen, fingen sie in den Test-trials an, S´ und S- willkürlich zu wählen, als ob sie die gelernte negative Assoziation von S- (keine Belohnung) verdrängten. Auch in S´/S´´ -trials wählten die Affen willkürlich, ohne einer klaren Regel.

Auch wenn die beiden Tests keinen Beweis dafür lieferten, dass die Affen logisch nach Ausschlussprinzip gehandelt haben, zeigt sich ein Trend in diese Richtung und vielleicht liefert eine veränderte Methode des Belohnungssystems und eine größerer Anzahl an Versuchstieren in der Zukunft positive Ergebnisse. Es wären also weitere Tests nötig, um Klarheit darüber zu erlangen, ob Weißbüscheläffchen fähig sind nach dem Ausschlussprinzip zu handeln.

4. Introduction

Every organism experiences its world. To survive and reproduce in its environment it must make decisions and solve problems even when confronted with incomplete information. One method to deal with fragmentary information is termed inferential reasoning, which involves drawing an association between a visible and an imagined event (Premack 1995). Such abilities to reason allow animals to efficiently solve physical problems in the world, as well as to be aware of new challenges and to discover new strategies.

Experience and a core knowledge system are important for developing an understanding of the world that permits individuals to draw inferences and to solve novel problems. Core knowledge is possessing comprehension about the causality of certain physical events, and it supports the use of logical inference in choosing among alternatives to maximize, for example, food intake (Call 2006).

One kind of reasoning ability is inferential reasoning by exclusion. It has been defined as "the selection of the correct alternative by logically excluding other potential alternatives" (Call 2006). It has also been described as the ability to reason about an excluded alternative, and is one of the ways in which an animal can learn about what is not immediately perceptible (Bermúdez 2006).

For purposes of this study, I use the concept of inferential reasoning by exclusion when an unfamiliar novel stimulus (i.e., a stimulus that does not already have a learned association with a category label) is selected over a set of stimuli that are already defined. Human children are known to learn by exclusion, for example in acquiring new vocabulary (Dixon 1977; Ferrari et al. 1993). In the literature inferential reasoning by exclusion is often referred to as "fast mapping," which is restricted to linguistic situations and appears to be mediated by general learning and memory mechanisms (Kaminski et al. 2004). When presented with a novel name in the presence of a novel item, children invariably match that name to the novel item (Wilkinson et al. 1998). It is as if children presume that every item has only one name and that every word can be matched to one item.

The question arises can non-linguistic animals solve inferences by exclusion? Results of several studies indicate that some non-human species, such as chimpanzees, dogs, dolphins and sea lions, are able to infer by exclusion when presented with familiar and novel items (Erdöhegyi et al. 2007; Call 2006; Schustermann and Kastak 1993; Tomonaga 1993).

The methods and paradigms found in the literature to test animals' exclusion abilities vary considerably. Kaminski et al. (2004) demonstrated fast mapping in a Border

collie, named Rico. Rico knew the labels of over 200 objects. He retained this knowledge over time and acquired new labels through his owner, who introduced him to new items by presenting them and saying their name two or three times. He had the ability to acquire the relation between a word and the object that the word refers to and was able to retrieve the requested objects immediately. To test the dogs' fast mapping ability, an experimenter placed a novel item together with seven familiar items in an experimental room. Rico then inferred the names of novel items by logically excluding those items he knew and correctly retrieving the novel items right away, as well as four weeks after the initial exposure.

Beran and Washburn (2002) employed a different method to demonstrate inference by exclusion. They tested three chimpanzees, who were language competent, in a computerized matching-to-sample task (MTS) in which exclusion of certain comparisons was possible. The chimpanzees were able to establish numerous associations between geometric symbols, i.e. lexigrams, and items found in the environment. After having learned the lexigram-to-item associations, the chimpanzees were exposed to new lexigrams. In all experiments in which the exclusion principle could be used, the response of the chimpanzees was consistent with such a use. Similar to humans in previous studies, the chimpanzees responded to the task as if each defined lexigram name must be associated with only one item and thus only lexigrams without defined items were appropriate labels for stimuli without prior lexigram associations.

Another study has also demonstrated the existence of inferential reasoning by exclusion in a female chimpanzee. Hashiya and Kojima (2001) showed her a set of two pictures (of someone she knew and someone she did not know) and an unfamiliar voice. The chimpanzee correctly matched the unfamiliar voice to the unfamiliar picture. Hence, there is a growing body of evidence affirming the presence of exclusion performances in various species. However, previous studies have mainly concentrated on non-human primates, e.g. chimpanzees, while other primates, such as the Common Marmoset, are largely ignored.

The Common Marmoset (Callithrix jacchus) is a small New World monkey and lives in a cooperative social breeding system. Because of its distinctive social life it has mainly been tested experimentally in observational conditioning, imitation and stimulus enhancement tasks (Voelkl and Huber 2000, Caldwell and Whiten 2003, Voelkl et al. 2006), but their individual learning skills have been rarely investigated (for a review see, Huber and Voelkl 2009). However, human medical research often resorts to marmosets for clinical studies, as well as to make comparisons to human neurological and neuropsychiatric disorders. In such studies, the marmosets often

perform on touch-sensitive screens where they must discriminate among various stimuli to solve matching-to-sample or reversal learning tasks (Crofts et al. 1999; Roberts et al. 1990; Stevens et al. 2007; Spinielli et al. 2004). Although these studies did not focus on individual learning abilities, it is clear that marmosets are trainable to a high and consistent level of performance on a wide range of working memory tasks (Ridley and Baker 1991, 1993).

Since previous studies have not considered aspects of higher cognition, such as reasoning or causal inference, the goal of the present study was to determine the ability of marmosets to draw inferences by exclusion. For this I employed a touch-screen methodology in connection with the paradigm established by Aust et al. (2008). The paradigm has proved to be an adequate method to test learning by exclusion with different species under equal conditions. Furthermore, the usage and development of this methodology has a tradition in our department, and the method facilitates cross-comparison of the results. The two-choice task developed by Aust and colleagues has been previously conducted on dogs, humans and pigeons. Aust's study on inter-species differences showed that dogs and humans were able to reason by exclusion, but not pigeons. My working hypothesis is that the marmosets, like chimpanzees and dogs, can learn to solve tasks by the use of exclusion reasoning.

Two sets of tests were designed to ensure the validity of the conclusions. The first set, referred to as Choosing by Exclusion, tested for a preference for novel stimuli by excluding familiar ones. The second set of tests, Learning by Exclusion, examined the stability of the (previous) preference for novel things, since the first test is not conclusive in this respect. The animals' preference for novel stimuli in the first test, on the one hand, could have been resulted from neophilia, a tendency of animals to prefer new things. On the other hand, it may be due to another strategy, neophobia, which designates an avoidance of novel things and a preference to familiar ones.

Individuals who significantly choose novel stimuli in the first test would undergo a second test to ensure that they chose according to exclusion or neophilia. For this, novel stimuli from the first test would be presented in the second test together with additional novel stimuli. Animals that continued to choose the novel stimuli in Test 1, may have done so because they already defined the stimuli as positive, and the possibility of neophilia can be excluded. Individuals who avoided all novel stimuli in Test 1 did not participate in Test 2 since neophobia would bias their learning behavior.

5. Methods

5.1 Animals Tested / Subjects

The animals I worked with were eight adult Common Marmosets, Callithrix jacchus (4 males and 4 females), from three different captive families at the Department of Cognitive Biology at the University of Vienna (Tab. 1). Each family lived in an indoor cage (250 x 250 x 250 cm), equipped with branches, ropes and platforms. The animals were fed a diet of fruit, vegetables, marmoset jelly, protein and vitamin supplements and water ad libitum. In Common Marmosets, all males have dichromatic vision, while some females are trichromates (Yeh et al. 1995). For purposes of this study, it was not necessary to know which tested females had di- or trichromatic color vision, since the stimuli I used differed in color and shape. Hence, animals were trained to be attentive to details of pictures other than color and shape.

Tab. 1: Overview of the tasks the subjects (N = 8) had to perform. The subjects (ME, SP, PA, etc.) were counterbalanced by two groups (A and B). Squares with crossed out letters represent incomplete performances.

SUBJECTS	TASKS								
	Touch-training	Pre-training 1	Pre-training 2	Test-training	Test 1a-Choosing by exclusion	Extra-training	Partial reward training	Test 1b-Choosing by exclusion	Test 2-Learning by exclusion
ME	A	A	A	A	~~A~~				
SP	A	A	B	A	A	A	A	A	
PA	A	A	A	B	B	B	B	B	B
WI	A	A	B	B	B	B	B	B	B
JAC	A	A	B	A	A	A	A	A	
LO	A	A	B	A	A	A	A	A	
JA	A	A	A	B	B	B	B	B	
FI	A	A	A	B	B		~~B~~		

5.2 Experimental set-up

The computer-controlled experiments were conducted in an experimental cage, which was visually isolated from the marmosets' home cages. The experimental chamber (146 x 40 x 110 cm) contained a platform (29 x 14.5 cm), which was placed 42.5 cm above the floor of the cage. The chamber was connected to the home cages through a tunnel system to lead the subjects to the experimental set-up. A computer was installed on a trolley directly in front of the experimental chamber, so that it could be easily brought into position (Fig. 1 a/b). The screen of the computer was touch-sensitive. While working on the computer, the marmosets sat in front of the screen on the platform. All stimuli were presented at the height of the animal's eyes. The monkeys could reach through the wire mesh (wide 2 x 2 cm) to touch the sensitive screen. Turning the monitor in front of the experimental cage shaded the chamber which ensured the vividness of stimuli having bright colors. Further, the experimental chamber was darkened to avoid reflections from the sun.

The program CognitionLab Light-Version 1.2 (created by Michael Steurer) was used as software on the computer (PC) and generated images on a black or white screen. It controlled contingencies and counted correct/incorrect choices, any touches on the screen, total number of errors and measured the duration of all trials. Furthermore, it provided two different acoustic signals and changed the stimuli. The length of the ITIs (intertrial interval) was 1-2 seconds. The sound of an acoustic signal for one second indicated the onset of availability of reward. I stood behind the monitor and conveyed the reward (mealworms or small pieces of bananas) from above using a pair of tweezers. The reward was presented in the center of the screen. Animals had been habituated to the experimental cage in previous experiments. The experimental design is specified in Table two.

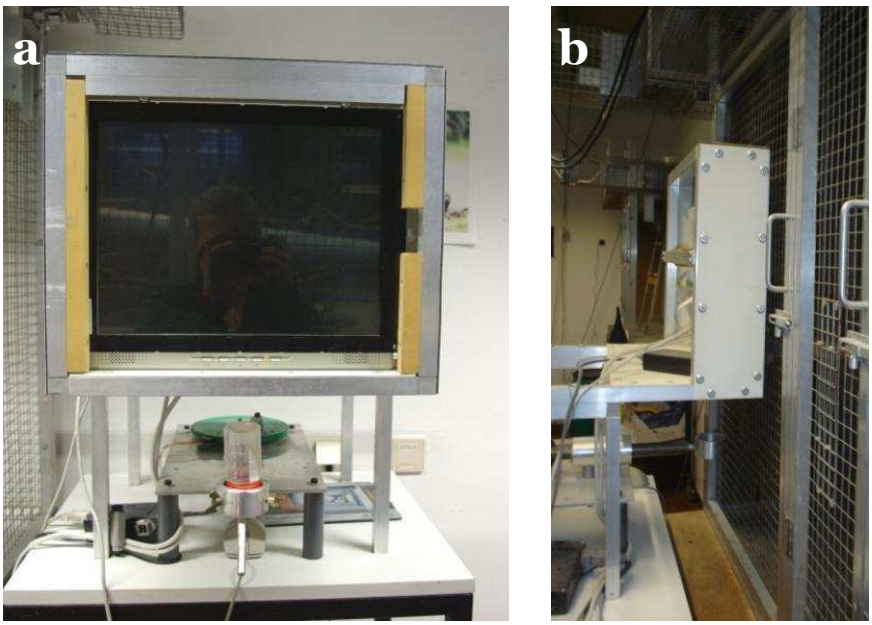

Fig. 1: Touch-sensitive screen used for experiments. **a** Apparatus holding the computer touch-sensitive screen. **b** Touch-sensitive screen positioned before homecage of marmosets.

Tab. 2: Experimental design - Overview of the experiment.

Training:

Touch-training

Pre-training:

-Pre-training 1

-Pre-training 2

Test-training

Tests:

Test 1a-Choosing by exclusion

Interspersed training:

-Extra training (Extra training + Extra test´)

-Partial reward training

Test 1b-Choosing by exclusion

Test 2-Learning by exclusion

5.3 General procedure

I applied the experimental design described in the study by Aust et al. (2008). The marmosets were naive to computer-controlled procedures and to two-choice tasks, as well. Therefore the subjects had to learn first to touch a projected stimulus on a computer-screen. After acquiring this skill, they were trained in different discrimination tasks to become habituated to the new type of procedure and finally to the ultimate discrimination task. The procedure was a two-choice task in which the animals had to discriminate between pairs of images presented on the touch-sensitive-screen. Each trial involved the simultaneous presentation of two stimuli. They were projected onto a black background in fixed positions at about monkeys' eye-level. The presentation of the pairs appeared in the middle of screen, but one stimulus was set somewhat right of the middle and the other one somewhat left of the middle screen. If choosing the correct alternative (S+) they were rewarded by a melodic acoustic signal for one second and a treat, and the trial was terminated. The sound of the acoustic signal indicated the onset of availability of reward. Giving an incorrect response (S-), the screen turned red for 3 seconds as a punishment signal and the same trial was presented again until the monkey corrected itself in the correction trials. After the termination of a trial, the screen stayed black for an ITI for a minimum of one to a maximum of two seconds, until the next trial started. If the area of the screen outside either stimulus was touched nothing happened, and the stimuli remained visible. Thus, the stimuli remained on the screen until the animal made a valid choice. To avoid side preferences the position of the individual stimuli were varied randomly from trial to trial. To avoid a possible bias for previously acquired picture preferences, the subjects were counterbalanced in two groups (A and B). For group A, half of the stimuli were positive and for the other half negative, and for group B this was reversed. In this fashion, the stimuli that were negative for group A were positive for group B and vice versa.

The conducted tests involved rewarded training trials (food + visual/acoustic signals) and unrewarded test trials. Each trial had an ITI of one second. Due to the fact that the subjects could not cope with the change from rewarded training trial to unrewarded test trial, I conducted trainings with the marmosets between the test phases.

All eight marmosets were trained individually in the experimental cage. Training and test sessions were performed between 10:00 h and 14:00 h on three to four days per week. The maximum number of individual sessions was three per day depending on attention and motivation. Normal daily food was given only after the sessions, to sustain the marmoset's motivation for the food reward.

5.3.1 Training

The animals had to complete different training stages to acquire the method of a two-choice task. First, they had to learn to touch a projected stimulus on a screen in the Touch training, then they had to acquire the task of the two-choice procedure in two Pre-trainings and lastly they had to learn the training stimuli for the final task in the Test-training. After the Touch training, the procedure remained unchanged except for the number and contents of the stimuli and, as aimed for, an enhancement in the level of complexity.

5.3.1.1 Touch training

In the Touch training, the animals (N = 8) were encouraged to touch the stimulus first with pieces of banana that were stuck onto the screen at the place of the later stimulus position and later without the banana, but with the same stimulus supervised by acoustic and visual signals (30 trials per session). The stimulus was a colorful squared picture (6 x 6 cm) projected on the center of a black screen which remained until the monkey terminated the trial.

5.3.1.2 Pre-training:

For both Pre-training phases, the criterion was set at ≥ 20 correct first choices (which equals 66.7%) in four out of five consecutive sessions. I counted the number of correct first choices (%) per individual (N = 8) and per session (30 trials). To complete this phase, the animals had to accomplish a minimum of 4 consecutive sessions to reach the criterion of the discrimination procedure, whereby I actually had them run a minimum of 5 sessions to enhance learning. In Pre-training 1, all subjects were assigned to one group (A) which had the same contingencies concerning individual training pictures, whereas in Pre-training 2 the subjects were assigned to two groups (A and B).

5.3.1.2.1 Pre-training 1

In Pre-training 1, the marmosets learned to discriminate between two stimuli (e.g. a blue rectangle was set as the positive stimulus S+, and a yellow circle was set as the negative stimulus S-). The stimulus size was 4.5 x 4.5 cm.

5.3.1.2.2 Pre-training 2

In Pre-training 2, the number of pictures increased and became more complex. The task for the monkeys went beyond looking at simple shapes or single-colors. Unlike in Pre-training 1, the shape/color preferences would no longer be sufficient to discriminate between the pictures. Three pictures contained close-up views of underwater landscapes and the other three showed painted pictures of the artist Toulouse Lautrec. For four of the subjects the paintings were assigned as positive stimuli (S+) and the underwater pictures as negative (S-). The other four subjects had the assignments reversed. All stimuli were multi-colored and had no definite shape. Pictures had a size of 4 x 4 cm.

5.3.1.3 Test-training

The Test-training included the training stimuli for the final task. It consisted of 4 positive (S+) and 4 negative (S-) pictures of objects (training stimuli) like a cup, a ball or a present, in different colors with a size of 5.3 x 5.3 cm (Figure 2). They were presented with an ITI of 1 sec. on a white screen. There were 16 possible S+/S- pairings, presented twice a session, which varied randomly in 32 trials. The criterion of mastery was set at ≥ 28 correct first choices out of 32 trials per session (which equals 87.5%), in at least 5 of 7 consecutive sessions. In the other two sessions, the animals should perform at least correctly in 22 trials (which equals 68.75%).

Training stimuli

Fig. 2: The eight training stimuli presented simultaneously as pairs of S+ and S- in 32 trials a session.

5.3.2 Tests

5.4.2.1 Test 1a-Choosing by exclusion

The first test (Test 1a-Choosing by exclusion) contained 32 trials per session, involving 28 familiar training trials (S+/S-) and four interspersed test trials (S´/S-). A test trial presented a yet undefined novel stimulus (S´) (Fig. 3) together with an already familiar negative stimulus (S-) (Fig. 2). The rationale of the test was the following: Subjects choosing by exclusion should reject the S- because of their prior associations with the negative class and instead choose the hitherto undefined S´ to avoid categorical inconsistencies. By contrast, subjects with a propensity to choose a familiar stimulus in the presence of a novel alternative should prefer S- (Aust et al. 2008). The entire test was split into two cycles, each of which included 4 sessions with 16 possible S´/S- combinations. When the two cycles were pooled, the 16 possible S´/S- combinations were presented twice in 8 sessions. For pooled data (n = 32) the significance level was set at ≥ 22 choices (≥ 68.75%) which equal P = 0.025. For the unspooled data (n = 16) the significance level was set at ≥ 12 choices for one stimulus type which equals ≥ 75% and P = 0.038 as reliable probability for a choice preference. A preference was inferred when a subject chose the respective stimuli in ≥ 12 trials out of 16 in at least one of the two cycles and in ≥ 22 trials out of 32 when the data of the two cycles were pooled.

Test stimuli

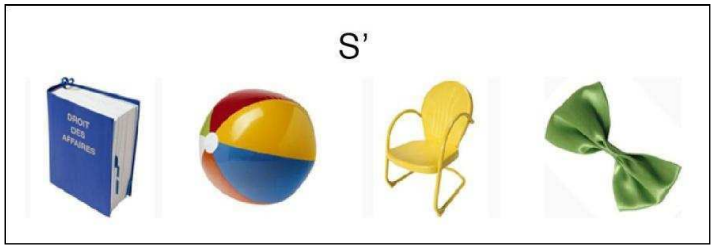

Fig. 3: The four test stimuli (S´) presented together with negative training stimuli (S-) in the choosing-by-exclusion experiments.

5.3.2.2 Interspersed training:

If the animals did not reach the criterion in Test 1a-Choosing by exclusion, they received Extra training. If the criterion of the Extra training was not achieved, they went through a Partial reward training. Both trainings aimed at strengthening the meaning of the negative class members (S-), even in situations without positive/negative feedback.

5.3.2.2.1 Extra training

The entire procedure had 16 sessions (each session contained 32 trials) alternating training and test sessions (Extra test´). After each training session a test session followed immediately. The training comprised 4 positive (S+) and 1 negative (S-) training stimuli that were shown randomly as S+/S- pairs. The Extra test´ involved the same S+/S- stimuli from training, and additionally added S` stimuli, combined with S-. The rationale was that by reducing the number of possible S- stimuli, the complexity of the discrimination task would be lower. This amplification of the negative class membership (S-) intended to avoid that the monkeys (N = 6) would forget the learned association in unrewarded test trials. The performance in which the preference for S´ was inferred was set at ≥ 68.75% choices with the hypothesis of either choice by novelty (neophilia), avoidance (neophobia), or reasoning by exclusion.

5.3.2.2.2 Partial reward training

To further avoid any impact of unrewarded test trials, I tried to habituate the subjects (N = 7) to partially rewarded sessions, which means that some trials were without reward, acoustic signal and correction trials. A simple touch terminated those trials without positive or negative feedback. For the criterion of mastery, animals had to complete three different conditions which differentiated in their contingent of rewarded trials per session. One session contained 30 trials.

The first condition (condition 80%) included 25 rewarded trials, the second one (condition 70%) included 22 rewarded trials and the third condition (condition 60%) contained 19 rewarded trials. Within each of these conditions, the animals had to run a minimum of 5 consecutive sessions.

5.3.2.3 Test 1b-Choosing by exclusion

Test 1a-Choosing by exclusion was repeated but with new, thus undefined, test stimuli (S´) and was titled Test 1b-Choosing by exclusion.

5.3.2.4 Test 2-Learning by exclusion

The following second test (Test 2-Learning by exclusion) was looking for the animals' persistence for S´ when it was presented together with an undefined novel alternative (S´´) (Figure 4). A preference for S´ in Test 1 alone would be insufficient to show that animals can reason by exclusion, since there can be used more than one strategy in order to explain that subjects prefer S´. Only animals, who achieved positive results in Test 1-Choosing by exclusion, choosing significantly S´, were admitted to this test.
Again, the test sessions consisted of 28 training (S+/S-) and 4 intermixed test trials. This time, I presented in test trials one of the S´ and one out of four more novels, thus undefined stimuli (S´´). Each subject had to run 8 sessions, which were split in two cycles (each 4 sessions), the same as in Test 1-Choosing by exclusion. If animals inferred in Test 1, that S´ is a stimulus from a positive class member, than Test 2 would confirm that by animals pecking at S´ that is member of the positive class member and S´´ as undefined, novel stimulus. As an alternative mechanism, it could be considered that animals prefer novel things because they act according to the mechanism of neophilia, which means that animals have a propensity for all novel objects or pictures. If this were accurate for animals who achieved positive results in Test 1, they would have chosen the hitherto undefined S´´ in this test. It is be possible that neither neophilia nor reasoning by exclusion leads to the avoidance of S- in Test 1-Choosing by exclusion, because the individuals' choice-behavior could also have formed, without differentiating class memberships and the relationship between S+ and S´. If this would were the case, the animals would not show a clear preference for S´ or S´´ in Test 2 and would have chosen them arbitrarily.

Test stimuli

Fig. 4: Test stimuli in Test 2-Learning by exclusion. Four of the test (S´) stimuli belong to the positive class (S+) and four (S´´) to the negative class (S-).

5.4 Statistics

The Touch-training was evaluated by counting the correct touches. After five to seven touches they acquired the skill of touching a stimulus on the screen.

The performances during Training and Test were analyzed by counting the number of correct first choices of each individual per session with the criterion to reach a certain significance level. Sex-differences and age varieties were analyzed as a nonparametric test to compare two unpaired groups (Mann-Whitney Test, two-tailed P value, P = 0.05).

The hypotheses of equal choice-probability for either S´ or S-, in the Test 1-Choosing by exclusion and for S´ or S´´ in Test 2-Learning by exclusion were subjected to a binomial test to assess the means for either pooled (n = 32 trials, P = 0.025) or unpooled (n = 16 trials, P = 0.038) data.

6. Results

6.1 Training:

6.1.2 Pre-training:

6.1.2.1 Pre-training 1

All individuals acquired the Pre-training 1 (discrimination between two shapes) quickly requiring an average (± SD) of 5.3 (±0.46) sessions to reach the criterion (range: 5-6) (see Tab. 3, Fig. 5). All animals (except SP) reached a performance above the significance level (66.7 %) in the second session. One individual (WI) attained a significance level above 93.3% in the first session. No differences were found concerning the sexes of the animals and their results (Mann-Whitney Test: N1 = 4, N2 = 4, U = 8, p =0.8794) (Fig. 6). Likewise, no statistical difference was found concerning age-differences (Mann-Whitney Test: N1 = 5, N2 = 3, U = 6.500, p =0.8772) (Fig. 7).

Tab. 3: Classification of the individual subjects (N = 8) and performance – given as the session when the criterion was reached – in Pre-training 1.

Subjects	Group	Sex	Sessions
ME	A	F	5
SP	A	F	6
PA	A	F	5
WI	A	F	5
JAC	A	M	5
LO	A	M	5
JA	A	M	6
FI	A	M	5

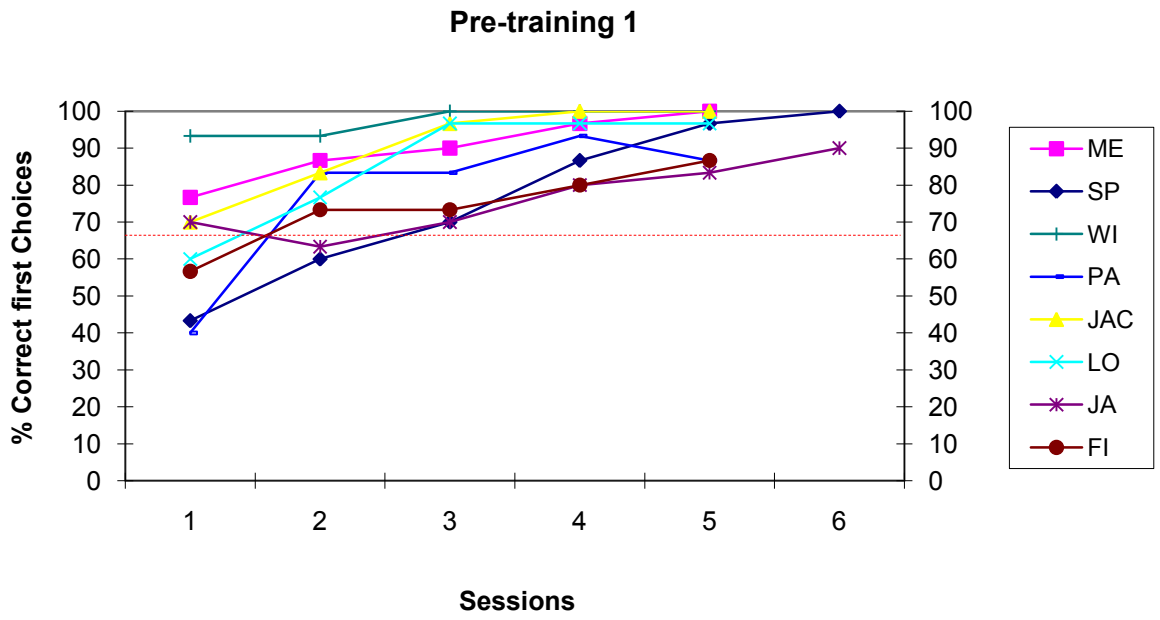

Fig. 5: Performance of Pre-training 1 (N = 8), in which the monkeys learned to discriminate between two geometric figures. The learning curves show the percentage of correct first choices to reach the criterion of 66.7% (dashed line, 20 out of 30 trials correct) in four out of five consecutive sessions.

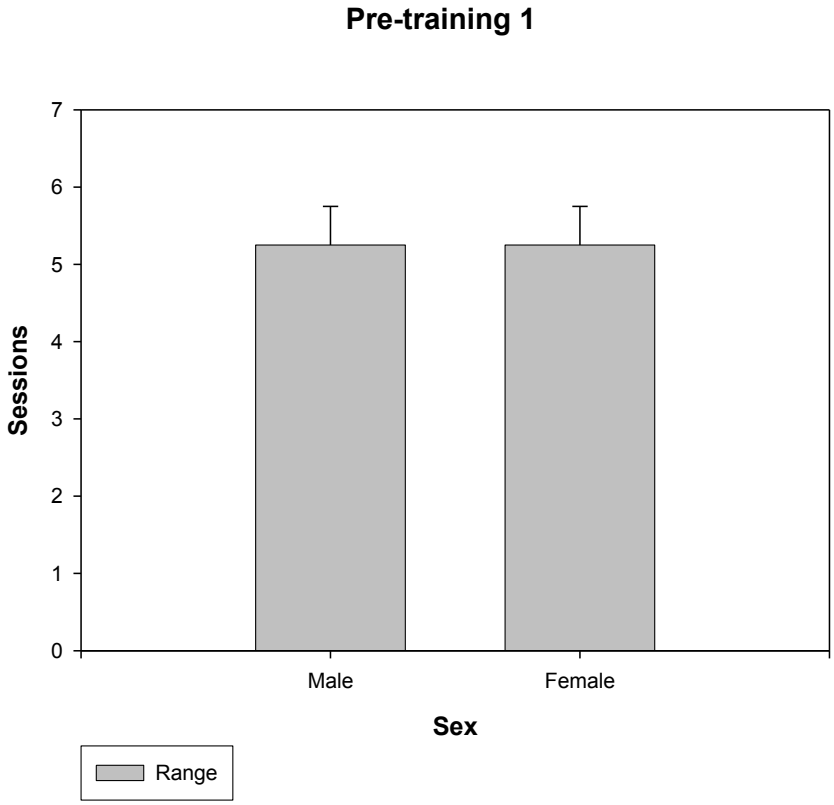

Fig. 6: Performance of the male (N = 4) and female (N = 4) individuals, given as average number (± SD) of sessions to reach the criterion.

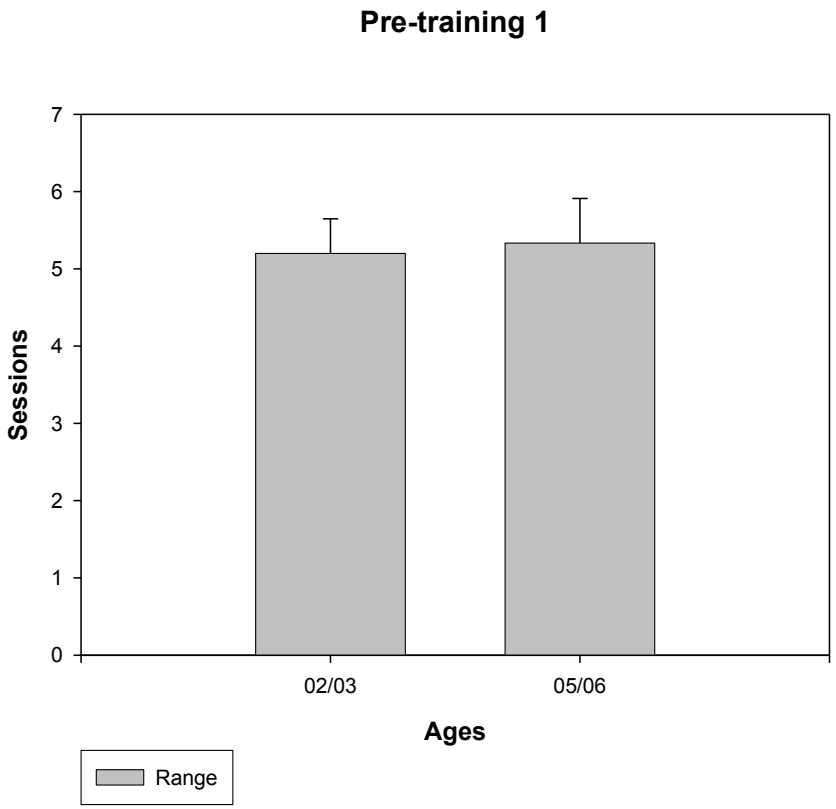

Fig. 7: Performances of the individuals in each age-class, those born in the years 2002/03 (N = 5) and those born in 2005/06 (N = 3), as average number (± SD) of sessions to reach the criterion.

6.1.2.2 Pre-training 2

On average (± SD) the animals needed 11 (± 7.67) sessions to reach the criterion of Pre-training 2, this is summarized in Table 4. The number of sessions to reach the criterion varied considerably among individuals (range: 5-28). One male monkey (FI) required twice the long as other monkeys, and extra sessions, to complete Pre-training 2 (Fig. 8). The females' performance was at its maximum after 15 sessions and the males' maximum was at 28 sessions. The performance of the female individuals ranged from 49.17% to 86.67 % correct first choices, while the male's ranged from 28.34% to 80%. Figure 9 illustrates the means (±SD) of both sexes (Mann-Whitney Test: N1 = 4, N2 = 4, U = 4.500, p =0.3851). Lumping the animals into older (N1 = born in 2002/2003) and younger classes (N2 = born in 2005/2006) revealed significant differences (Mann-Whitney Test: N1 = 5, N2 = 3, U = 0.000, p = 0.0357) (Fig. 10).

Tab. 4: Individual performance given in number of sessions required before reaching the learning criterion in the discrimination task of Pre-training 2. The individual subjects (N = 8) are counterbalanced by group- and sex-differences.

Subjects	Born	Group	Sex	Sessions
ME	2003	A	F	8
SP	2006	B	F	5
PA	2003	A	F	15
WI	2005	B	F	5
JAC	2006	B	M	7
LO	2003	B	M	8
JA	2003	A	M	12
FI	2002	A	M	28

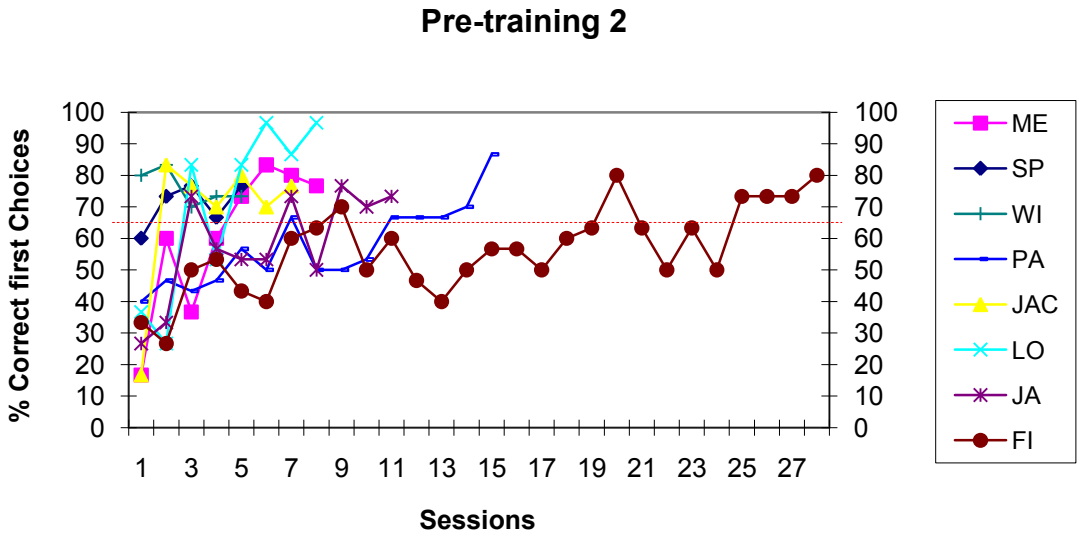

Fig 8: Individual learning curves for the Pre-training 2 tests (N = 8). Performance is shown in number of sessions required to reach the significance level (66.7%). The monkeys were considered trained when they discriminated between 3 S+ and 3 S- pictures in four out of five consecutive sessions.

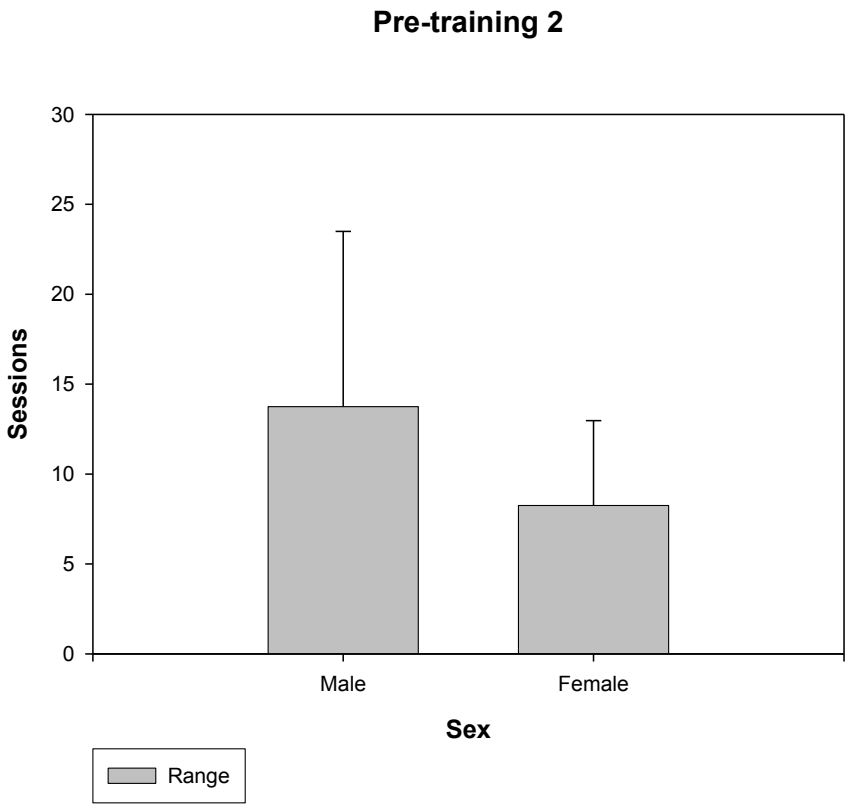

Fig. 9: Comparison of male (N = 4) and female (N = 4) performance, measured by the average number (± SD) of sessions required to reach the criterion.

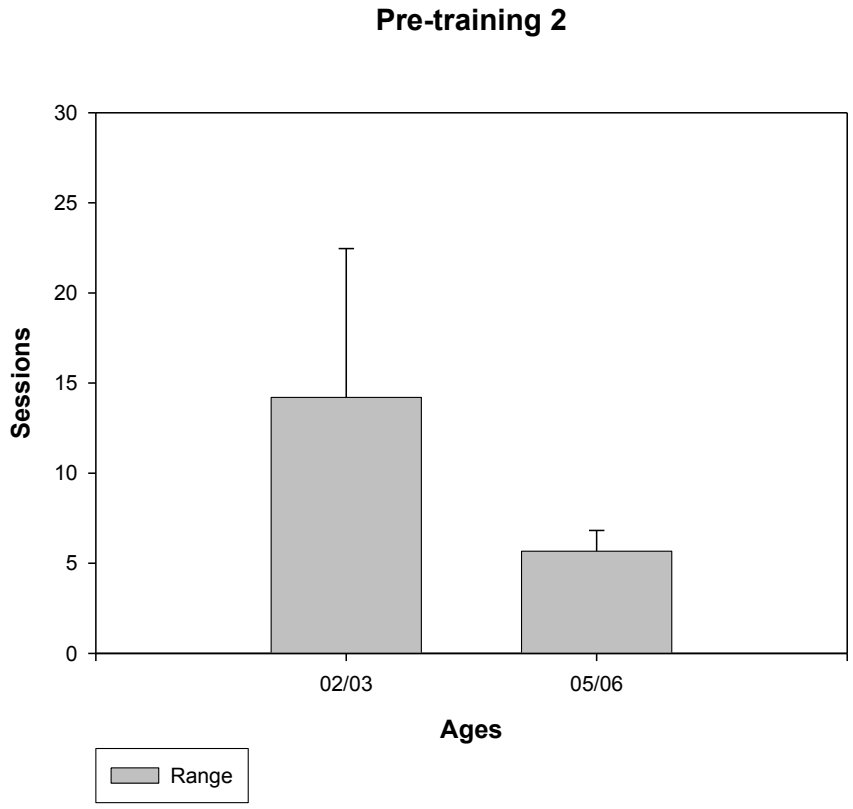

Fig. 10: Comparison of performance between the two age-classes, those born in the years 2002/03 (N =5) and those in 2005/06 (N = 3), measured by the average number (± SD) of sessions required to reach the criterion.

6.1.3 Test-training

The individual performances of the Test-training with an average (± SD) of 20.25 (± 7.17) sessions, is reported in Table 5. As in Pre-training 2, FI required the highest number of sessions to achieve the learning criterion of 87.5% (see Fig. 11). The performance of males and females did not differ significantly (Mann-Whitney Test: N1 = 4, N2 = 4, U = 4.500, p = 0.3851) (Fig. 12). There was also no age effect with regard to performance (older animals, i.e. those born in 2002/2003 and younger animals, i.e. those born in 2005/2006) (Mann-Whitney Test: N1 = 5, N2 = 3, U =3.500, p =0.2953) (Fig. 13).

Tab. 5: Performance of monkeys in the Test-training with training-stimuli. ME, SP, PA and WI are females, and JAC, LO, JA and FI are males.

Test-training Group	A/Subjects	Sessions	B/Subjects	Sessions
	ME	25	PA	11
	SP	19	WI	12
	JAC	15	JA	12
	LO	34	FI	46

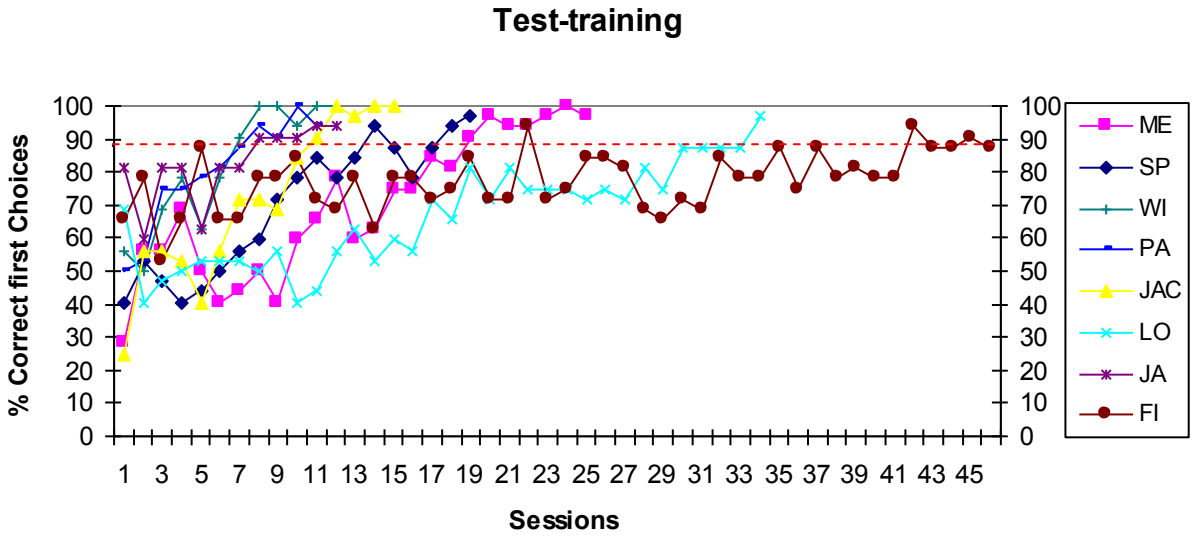

Fig. 11: Performance of the subjects (N = 8) in the Test-training, given as percentage of correct first choices. The dashed line indicates the learning criterion of 87.5%, which had to be obtained five times within seven sessions.

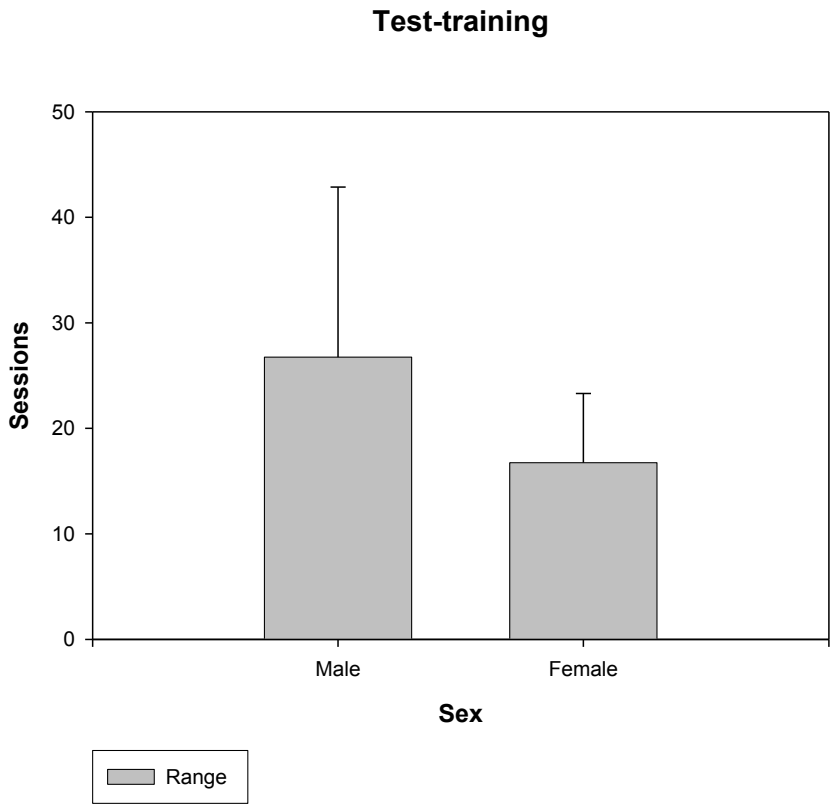

Fig. 12: Performance of males (N = 4) and females (N = 4) given as average number (± SD) of sessions to reach the criterion.

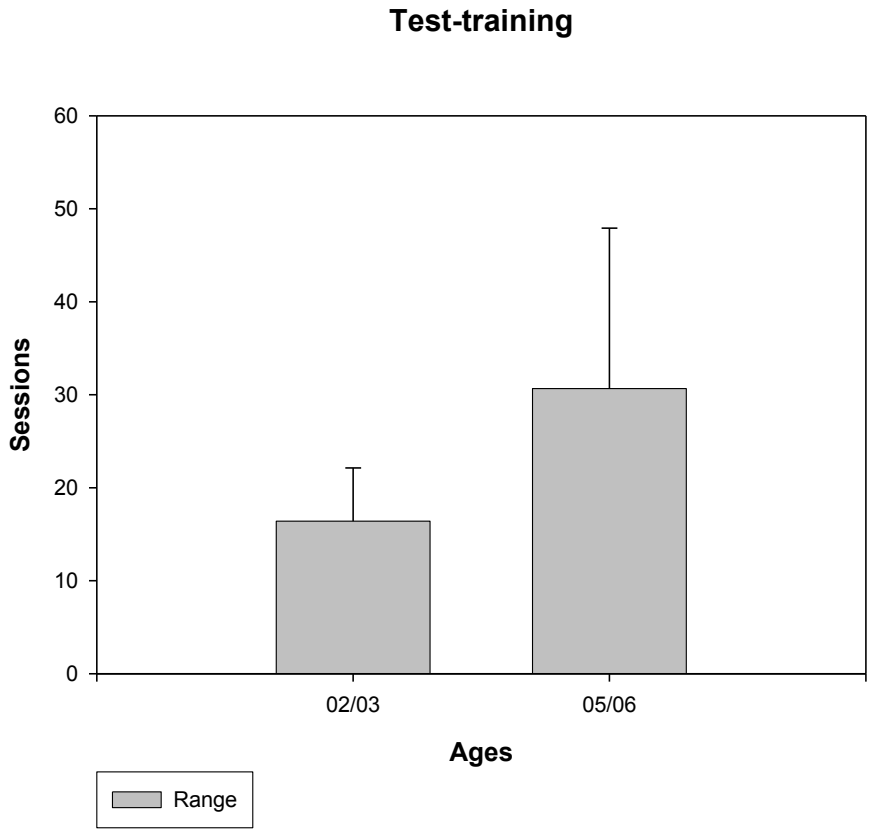

Fig. 13: Performance of two age-classes, older individuals that were born in the years 2002/03 (N =5) and younger individuals, born 2005/06 (N = 3).

6.2 Tests

6.2.1 Test 1a-Choosing by exclusion

The individual performances are reported in Table 5 with no significant differences in pooled cycles (significance level was set at ≥ 22 = ≥ 68.75% and P = 0.025). Only one performance deviated significantly from chance (significance level was set at ≥ 12 = ≥ 75% and P = 0.038): in the first cycle, FI chose S´ twelve times. Furthermore, two subjects, PA and JAC, had a 100% choice preference for S´ in the first session (Fig. 14), which however disappeared in subsequent sessions. Two other subjects (PA, WI) achieved results approaching the significance level in the first cycle (Fig. 13), but did not maintain their preference in the second cycle. One subject's (SP) choice performance for S´ was below 31.25% in the first and second unpooled cycles, as well as in pooled cycles, which indicates a preference for S-, most likely reflecting a choice behavior based on familiarity. I found no statistical evidence for a difference between the performance of males and females (Mann-Whitney Test: N1 = 4, N2 = 3, U = 4, p = 0.6286). Figure 14 shows that the means are on average very similar between the sex classes, but with a large inter-individual range. No significant difference was found between the two age-classes, older animals (born in 2002/2003, N1 = 4) and younger (born in 2005/2006, N2 = 3) (Mann-Whitney Test: N1 = 4, N2 = 3, U = 4.000, p = 0.5926) (Fig. 15). One female monkey (ME) was excluded from the analysis, because she failed to complete the test phase.

Tab. 6: Choices of S´ in Test 1a-Choosing by exclusion: scores out of 16 in cycles 1 and 2: scores out of 32 in both cycles (pooled). P-values (binomial test) are given in parenthesis and statistical significances in italics.

Test 1a-Choosing by exclusion

	Cy 1	Cy 2	Pooled
JAC	6 (0,227)	6 (0,227)	12 (0,108)
SP	4 (0,038)	4 (0,038)	8 (0,004)
PA	10 (0,227)	9 (0,402)	19 (0,189)
WI	10 (0,227)	9 (0,402)	19 (0,189)
JA	7 (0,402)	6 (0,227)	13 (0,189)
LO	7 (0,402)	5 (0,105)	12 (0,108)
FI	*12 (0,038)*	5 (0,105)	17 (0,430)

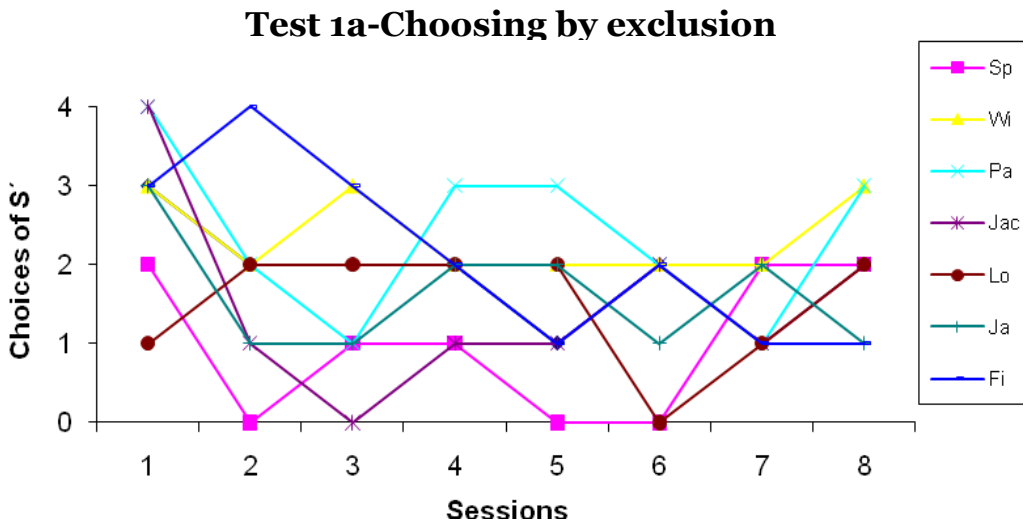

Fig. 14: Individual performance (N = 7) of Test 1a-Choosing by exclusion, given as number of S´ chosen in a session (max. 4).

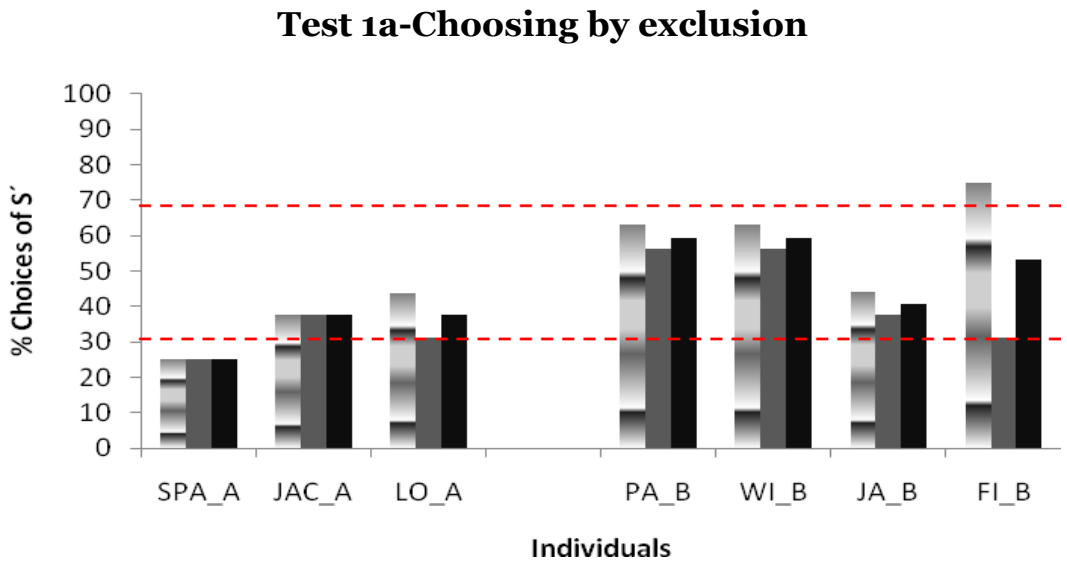

Fig. 13: Performance of all individuals (N = 7) compared with the two groups (A or B) (as percentage of S´ chosen in a session). The subjects had to run two cycles, the first bars (black-grey structured) show the first cycle, second bars (solid grey) show the second cycle and the last bars (solid black) indicate pooled cycles. The upper dashed line marks the level of performance beyond which animals had a significant preference for S´ in pooled cycles (≥ 68.75%). The lower dashed line indicates the level of performance below which animals had a significant preference for S- in pooled cycles (≤ 31.25%).

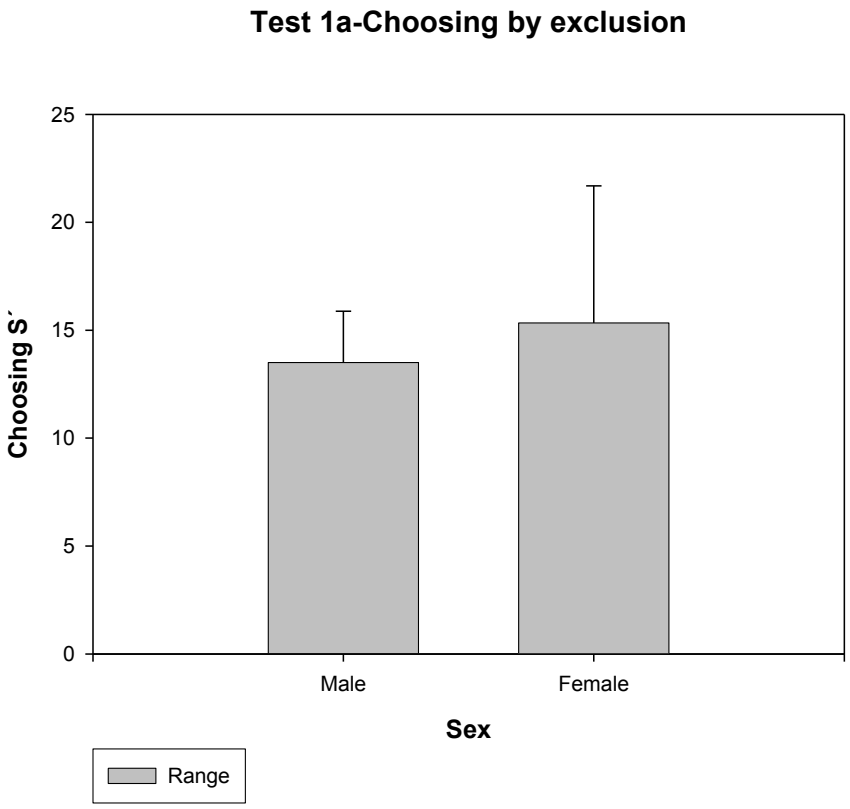

Fig. 14: Comparison of the performance of both sexes: males (N=4) and females (N=3) in Test 1a-Choosing by exclusion (given as the average number of choices of S´ ± SD) for 8 sessions with a choice possibility of 32 choices in all sessions.

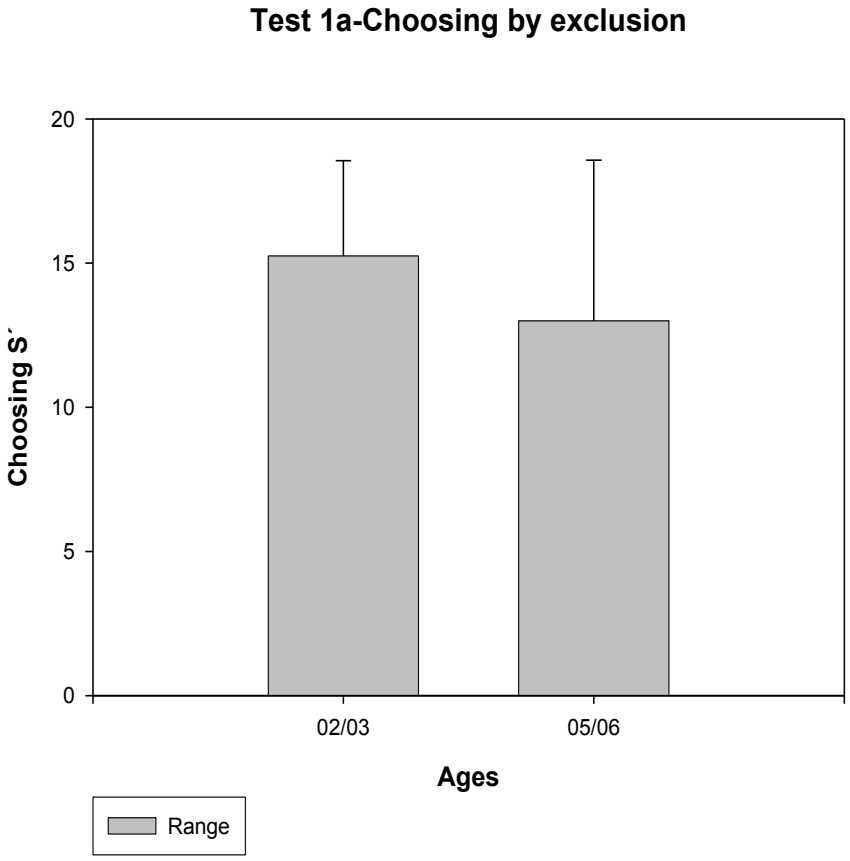

Fig. 15: Comparison of the performance of the two age classes, those born in the years 2002/03 (N =4) and those in 2005/06 (N = 3) in Test 1a-Choosing by exclusion, given as the average number of choices of S´ (± SD) for 8 sessions with a choice possibility of 32 choices in all sessions.

6.2.2 Interspersed training

6.2.2.1 Extra training

The entire procedure included 16 sessions (each session contained 32 trials). Training was immediately followed by its assigned test session (Extra test´). Only test sessions with relevance are described in Table 7 and Figures 16-19.
None of the subjects reached significant results in pooled cycles. Only one subject (WI) approached the significance level (75%) with 11 choices of S´ in the second cycle (Tab. 7 and Fig. 17), and only two subjects (PA and WI) preferred S´ in 100% of the trials in at least one session (Fig. 16 and 17). Again, SP preferred S-, as did PA and JA, in unpooled and pooled cycles. I found no statistical evidence for sex-differences between males and females (Mann-Whitney Test: N1 = 3, N2 = 3, U = 3.500, p = 0.8260) (see Fig. 18) No significant difference was found between the two age-classes, older animals (born in 2003, N1 = 3) and younger (born in 2005/2006, N2 = 3) (Mann-Whitney Test: N1 = 3, N2 = 3, U = 4.500, p =0.8260) (Fig. 19).

Tab. 7: Choices of S´ in the Extra test´: scores out of 16 in cycles 1 and 2: scores out of 32 in both cycles (pooled). P-values (binomial test) are given in parenthesis and statistical significances in italics.

	Extra test´		
	Cy1	Cy2	Pooled
JAC	7 (0,402)	6 (0,227)	13 (0,819)
SP	0 (0,00002)	1 (0,0003)	1 (< ,0001)
PA	5 (0,105)	5 (0,105)	10 (0,025)
WI	4 (0,038)	11 (0,105)	15 (0,430)
JA	3 (0,106)	2 (0,002)	5 (< ,0001)
LO	8 (0,598)	7 (0,402)	15 (0,430)

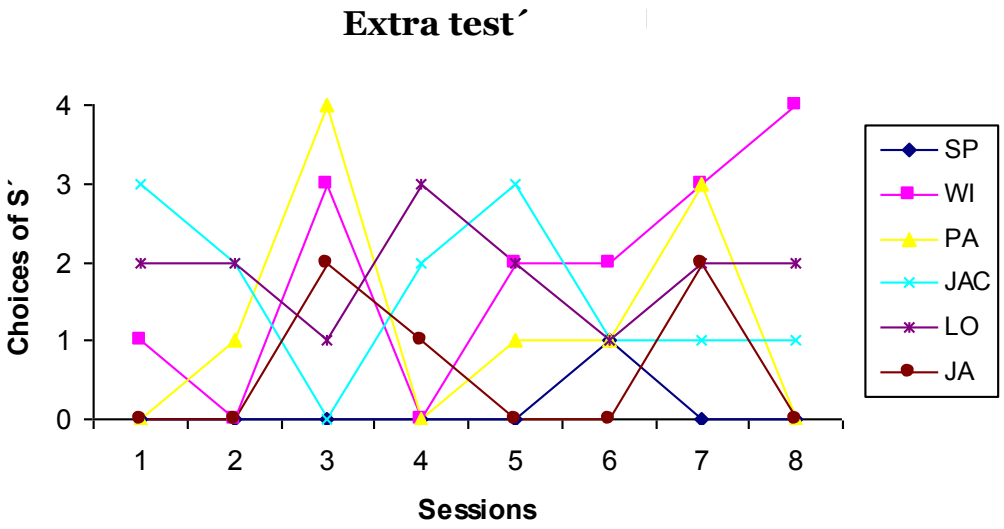

Fig. 16: Individual performance (N = 6) in the Extra test´, given as number of S´ chosen in a session (max. 4).

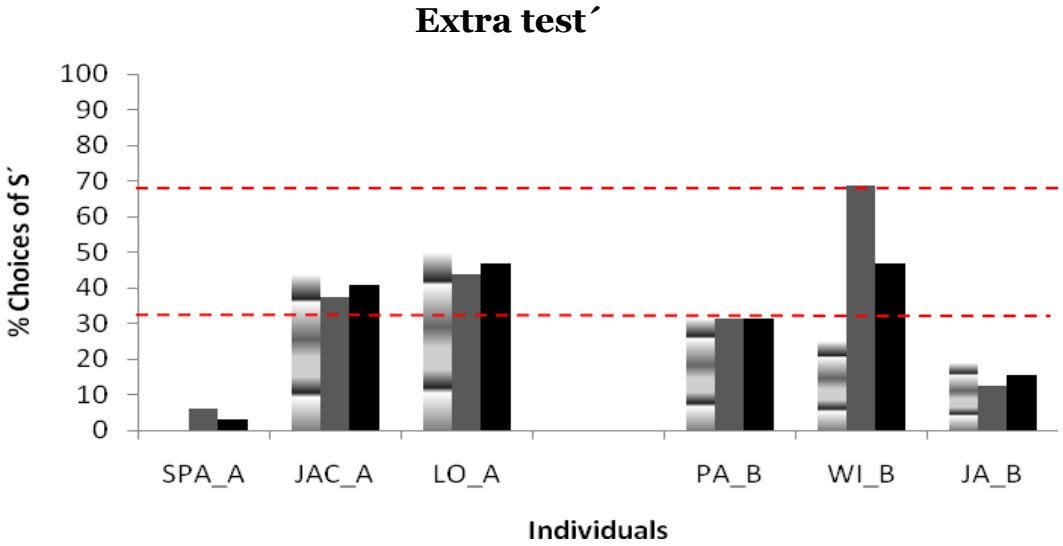

Fig. 17: Performance of all individuals (N = 6) compared with the two groups (A or B) (given as percentage of S´ chosen in a session). The subjects had to run two cycles, the first bars (black-grey structured) show the first cycle, second bars (solid grey) show the second cycle and the last bars (solid black) indicate pooled cycles. The upper dashed line marks the level of performance beyond which animals had a significant preference for S´ in pooled cycles (≥ 68.75%). The lower dashed line indicates the level of performance below which animals had a significant preference for S- in pooled cycles (≤ 31.25%).

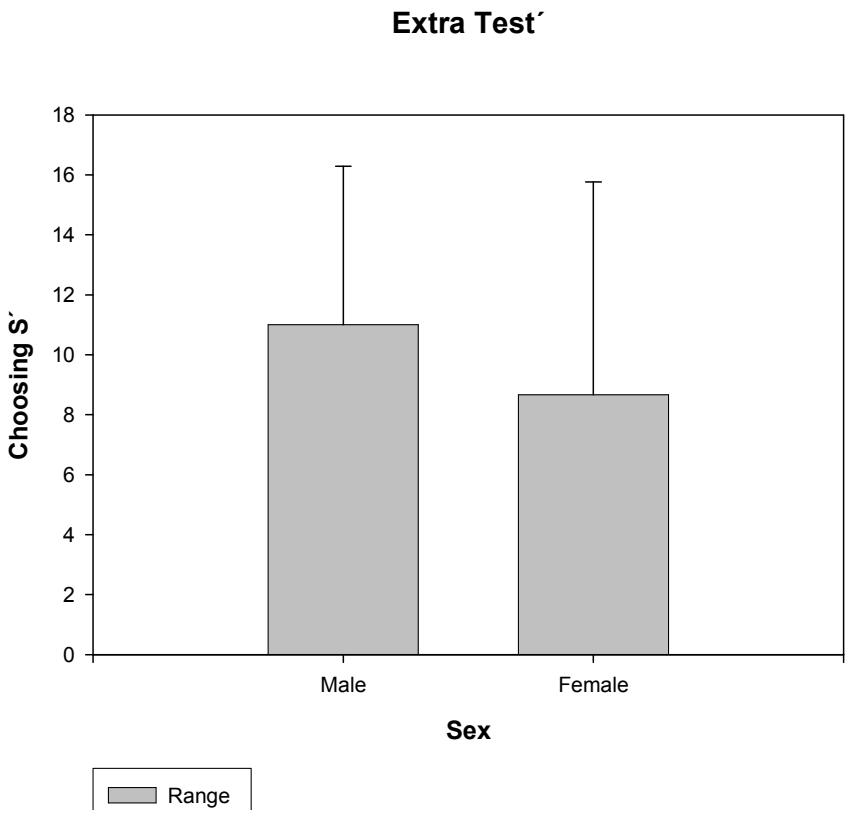

Fig. 18: Comparison of the performance of both sexes (male (N = 3) and female (N = 3)) in the Extra test´ (given as average number of choices of S´ ± SD) for 8 sessions with a choice possibility of 32 choices in all sessions.

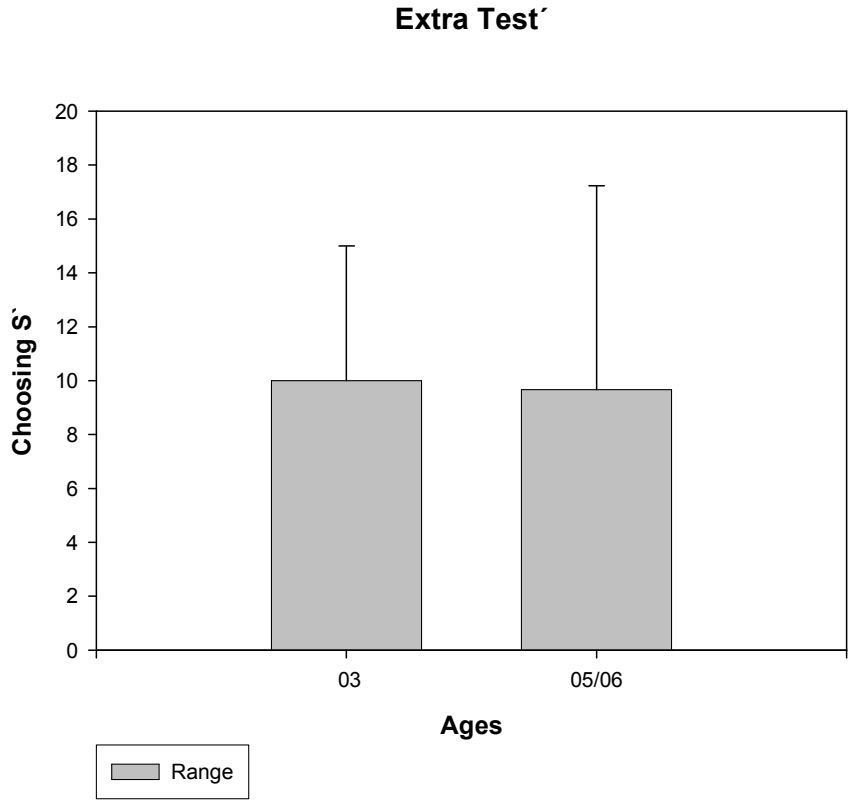

Fig. 19: Comparison of the performance of the two age classes, those born in the years 2002/03 (N =3) and those in 2005/06 (N = 3) in the Extra test´ (average number of choices of S´ ± SD) for 8 sessions with a choice possibility of 32 choices in all sessions.

6.2.2.2 Partial reward training

Almost none of the animals had difficulties in discriminating the training stimuli in partially rewarded sessions (see Tab. 8). Only FI had problems to achieve the learning criterion. Therefore, I stopped his training in the second condition (70% correct choices) after 42 training sessions because I did not want to force him beyond his already well trained stimuli. This would run the risk of affecting his motivation for computer-controlled tasks in the future. He was clearly frustrated and demotivated, these factors probably worked negatively on his attention and could have been the reason for his decreased training performance.

Tab. 8: Performance of individuals (N = 7) in the Partial reward training. Given is the number of sessions required to reach a pre-specified level of performance (60%, 70% or 80% correct choices).

	Partial reward training						
Ind	JA	JAC	LO	SP	WI	PA	FI
80%	5	7	11	5	5	5	17
70%	5	5	5	6	5	5	42....
60%	5	5	5	5	5	5	....

6.2.3 Test 1b-Choosing by exclusion

The previous Partial reward training enhanced the performance of only two subjects in comparison to Test 1a-Choosing by exclusion. Almost all animals reached equal results (Table 5), but two (PA and WI) out of six individuals reached significant results in the second and in pooled cycles (Tab. 9 and Fig. 21). SP maintained her choice preference for S-. Examining the individual performances in Figure 20, it is clear that PA and WI had the highest success rate in choosing novel stimuli and thereby indicate, at least, a trend. In six out of eight sessions, they made the same number of choices for S´. There was no significant difference found between males and females (Mann-Whitney Test: N1 = 3, N2 = 3, U = 3.000, p = 0.7000) (Fig. 22) or the age classes (older, born in 2003) and (younger, born in 2005/06) (Mann-Whitney Test: N1 = 3, N2 = 3, U = 3.000, p = 0.7000) (Fig. 23).

Tab. 9: Choices of S´ in Test 1b-Choosing by exclusion: scores out of 16 in cycles 1 and 2 (and the sum). Significant scores are given in italics.

Test 1b-Choosing by exclusion						
Ind	JA	JAC	LO	SP	WI	PA
Cyc 1	6	5	8	3	10	11
Cyc 2	4	6	6	1	*12*	*13*
Sum	10	11	14	4	*22*	*24*

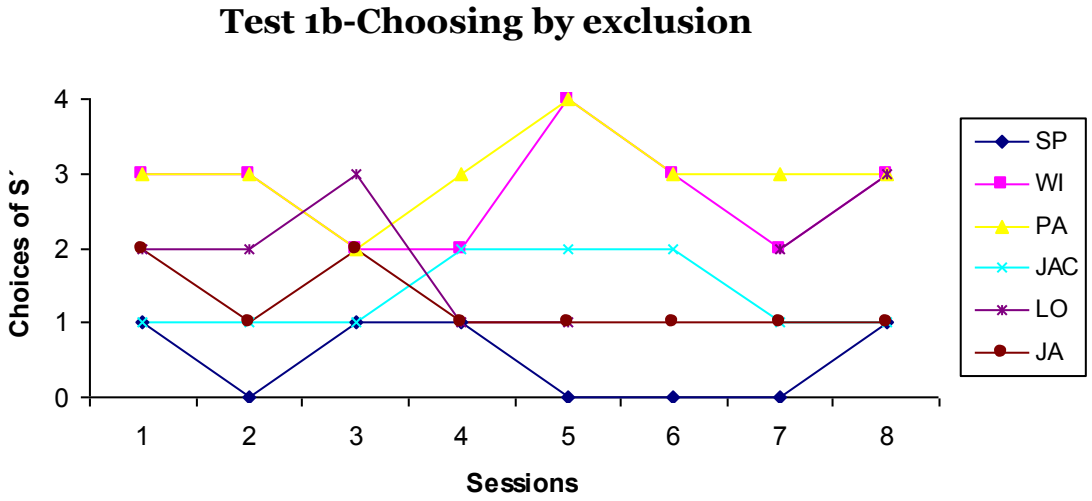

Fig. 20: Individual performance (N = 6) of Test 1b-Choosing by exclusion, given as number of S´ chosen in a session (max. 4).

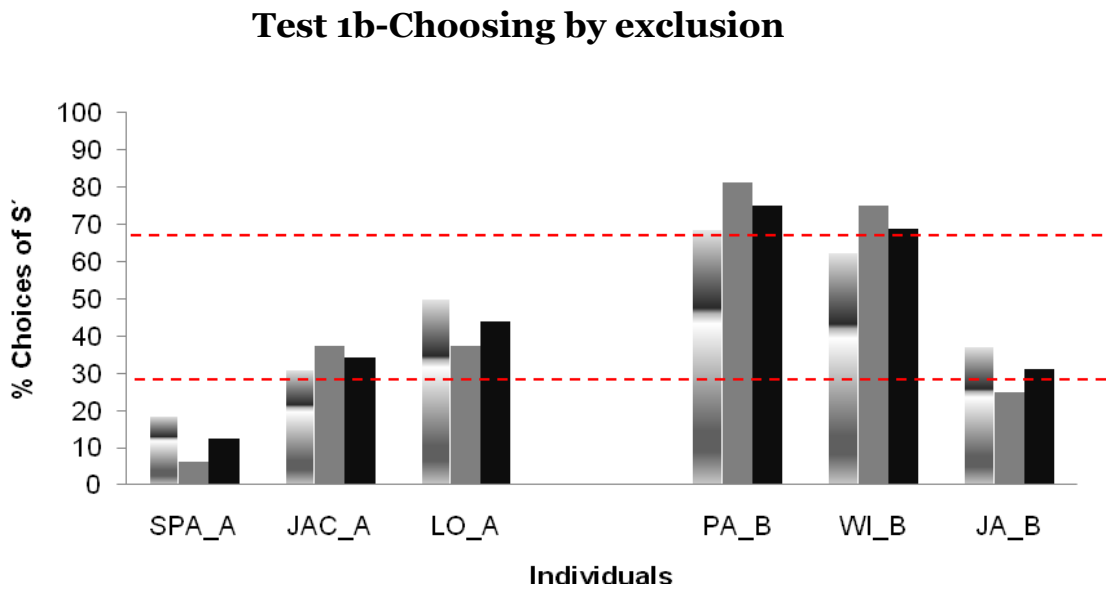

Fig. 21: Performance of all individuals (N = 6) compared to the two groups (A or B) (as percentage of S´ chosen in a session). The subjects had to run two cycles, the first bars (black-grey structured) show the first cycle, second bars (solid grey) show the second cycle and the last bars (solid black) indicate pooled cycles. The upper dashed line marks the level of performance beyond which animals had a significant preference for S´ in pooled cycles (≥ 68.75%). The lower dashed line indicates the level of performance below which animals had a significant preference for S- in pooled cycles (≤ 31.25%).

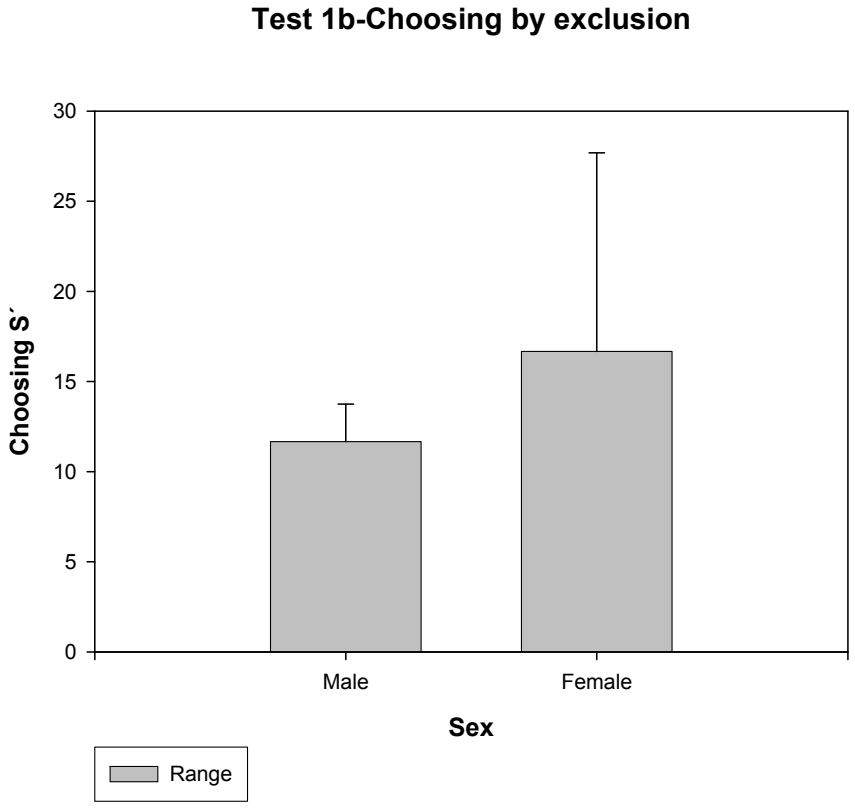

Fig. 22: Comparison of the performance of males (N =3) and females (N = 3) in Test 1b-Choosing by exclusion given as the average number of choices of S´ ± SD for 8 sessions with a choice possibility of 32 choices in all sessions.

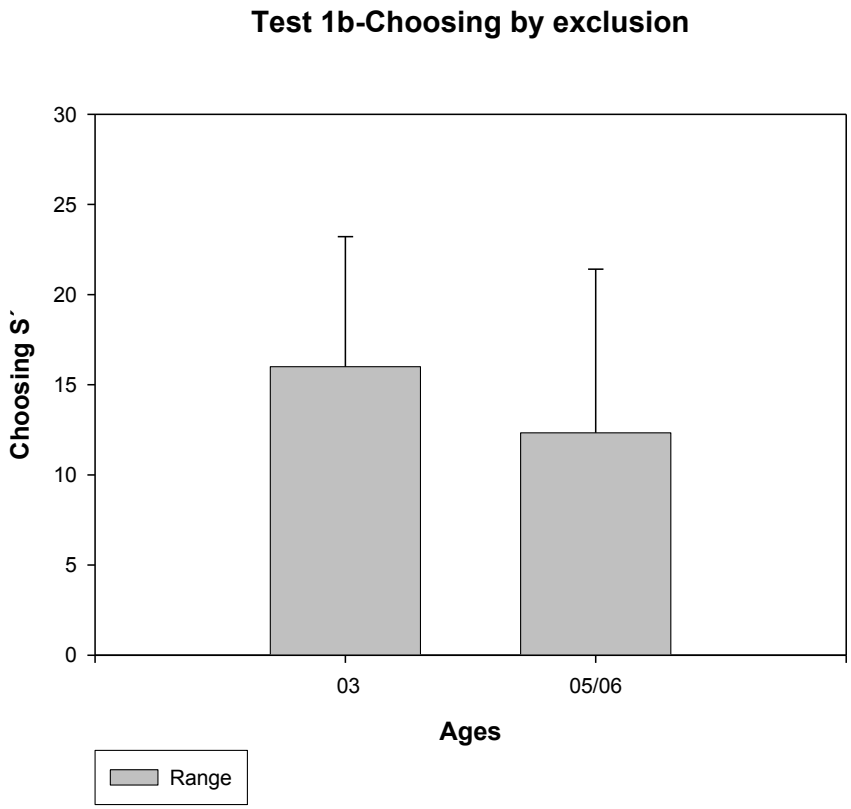

Fig. 23: Comparison of the performance of the two age classes, those born in the years 2002/03 (N =3) and those born in 2005/06 (N = 3) in Test 1b-Choosing by exclusion given as the average number of choices of S´ (± SD) for 8 sessions with a choice possibility of 32 choices in all sessions.

6.2.4 Test 2-Learning by exclusion

PA and WI reached significant results in Test 1b-Choosing by exclusion and were therefore tested again to confirm their persistence for S´ when presented together with an undefined novel alternative (S´´). The comparison of the results in Test 1b-Choosing by exclusion and Test 2-Learning by exclusion (see Tab. 10) demonstrates that subjects' (N = 2) preference for S´ was not maintained. Both animals showed fluctuating performance in subsequent test sessions (Fig. 24) and remained at an intermediate level of performance (Fig. 25).

Tab. 10: Choices of S´ in Test 1b-Choosing by exclusion and Test 2-Learning by exclusion: scores out of 16 in cycles 1 and 2: scores out of 32 in both cycles (pooled). P-values (binomial test) are given in parenthesis and statistical significances in italics.

	Test 1b-Choosing by exclusion			Test 2-Learning by exclusion		
Ind	Cy1	Cy2	Pooled	Cy1	Cy2	Pooled
JAC	5 (0,105)	6 (0,227)	11 (0,055)			
SP	3 (0,106)	1 (< 0,0001)	4 (< 0,0001)			
PA	11 (0,105)	*13 (0,011)*	*24 (0,004)*	10 (0,227)	9 (0,402)	19 (0,189)
WI	10 (0,227)	*12 (0,384)*	*22 (0,025)*	11 (0,105)	9 (0,402)	20 (0,108)
JA	6 (0,227)	4 (0,038)	10 (0,025)			
LO	8 (0,598)	6 (0,227)	14 (0,298)			

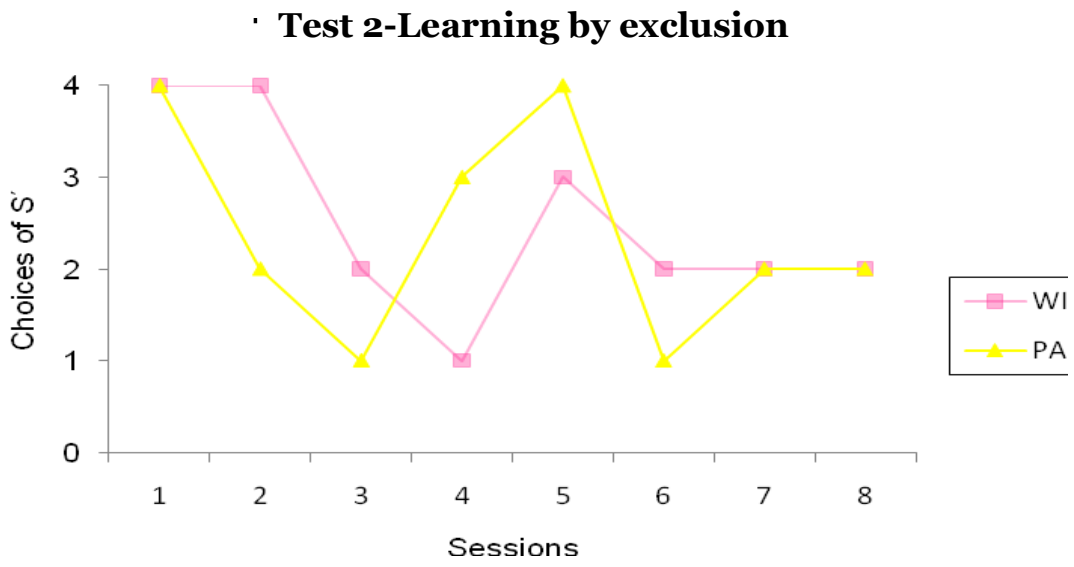

Fig. 24: Individual performance (N = 2) in Test 2-Learning by exclusion, given as number of S´ chosen in a session (max. 4).

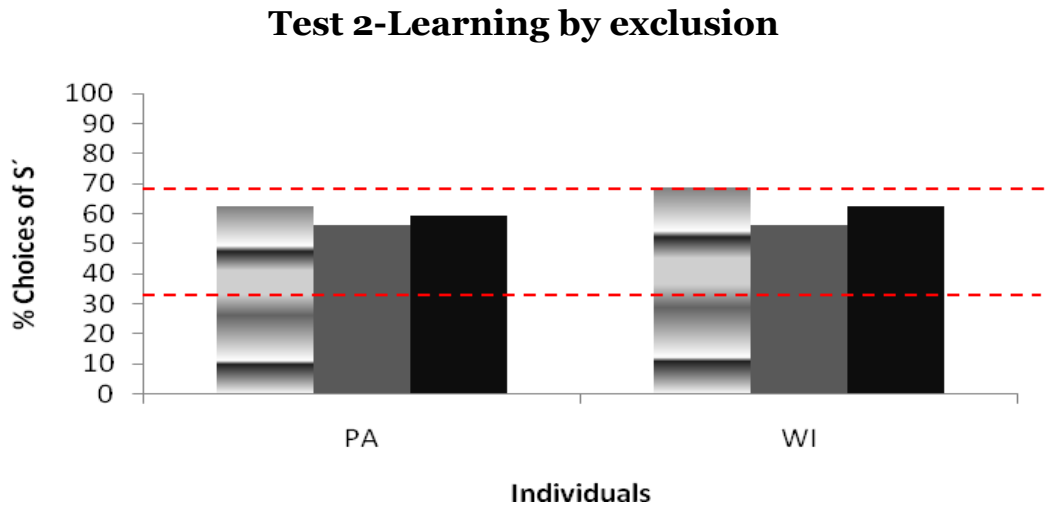

Fig. 25: Performance of all individuals (N = 2), both were in group B, given as percentage of S´ chosen in a session in Test 2-Learning by exclusion. The subjects had to run two cycles, the first bars (black-grey structured) show the first cycle, second bars (solid grey) show the second cycle and the last bars (solid black) indicate pooled cycles. The upper dashed line marks the level of performance beyond which animals had a significant preference for S´ in pooled cycles (≥ 68.75%). The lower dashed line indicates the level of performance below which animals had a significant preference for S- in pooled cycles (≤ 31.25%).

7. Discussion

The aim of the study was to investigate whether Common Marmosets are able to infer reasoning by exclusion in a discriminative touch-screen context. Based to my results, I am unable to provide sufficient evidence to positively assert that Common Marmosets have the cognitive skills to reason by exclusion. The only two subjects that preferred S´ in Test 1b-Choosing by exclusion failed to do so in Test 2-Learning by exclusion. If animals inferred in Test 1, that S´ is a stimulus from a positive class member, this would be confirmed in Test 2 when the animals select S´ as a member of the positive class and S´´ as an undefined novel stimulus.

At the onset of the study the monkeys were naive to computer-controlled tasks. However, all animals (N = 8) rapidly learned to touch a stimulus on the computer screen to obtain a food reward. They also had no difficulties in learning a two-choice procedure, first with simple stimuli (Pre-training 1) and thereafter with more complex ones (Pre-training 2). Nevertheless, the subjects did not master the discrimination task with equal ease.

What factors could account for inter-individual differences? First, performances and strategies of males and females may differ on several tasks due to sex hormones. These have been shown to play an important role in controlling animals' cognitive behavior. Sex-differences have been observed in a wide variety of animals, such as in the males of the Rhesus monkey (Macaca mulatta) and male human infants, both of which developed a toy preference for wheeled toys. In contrast, females showed greater variability in preferences (Hassett et al. 2008). Moreover, Aust et al. (2008) in their comparative study of inferential reasoning by exclusion in pigeons, dogs and humans found that male dogs were slower learners than females.

Sex differences also exist in the visual system of New World primates, in contrast to Old World primates. All marmoset males and other male New World primates are dichromates, but some females are trichromates (Yeh et al. 1995). However, it is not obvious that dichromatic marmosets are handicapped compared to trichromates, since dogs are also dichromates and proved able to complete the test in the afore-mentioned comparative study (Aust et al. 2008). Nevertheless, I ruled out visual difficulties a priori, since the training and test stimuli were different in shape and color.

The marmosets of this study did not show a significant effect of sex. These findings were not surprising because sex-differences would be more likely in a manipulation task than in a test on mental abilities (Yamamoto et al. 2004). Only one

of four male monkeys (FI) deviated from the group behavior by requiring extensively more sessions to learn the stimuli than the others. This result alone, however, would not account for sexual differences in marmosets.

Another factor which may affect an animals' cognitive abilities is age. Kendal et al. (2005) found that older marmosets were more innovative and explorative in manipulation tasks than younger individuals. This conclusion, however, is not supported in the existing primate literature (Boesch and Boesch, 1981, Fragaszy and Adams-Curtis, 1991, Hauser, 1988). The authors concluded that these unusual findings may come from increased manipulative competences based on more experience. All of my animals were unfamiliar with the apparatus and the procedure, and therefore none of them should have had an advantage over the other individuals (neither the older nor the younger). That may be the reason why I could not find significant differences concerning the age factor. In the study by Aust et al. (2008), the two youngest human participants failed to reason by exclusion, but the authors argued that more data was needed to investigate the possible contributions of age, sex and training history.

Since my investigation is a follow-up study of Aust et al. (2008) and since I used the same procedure and the same stimuli, it should be possible to compare the marmosets' learning behavior with that of the dogs. The female dogs of the pre-study needed on average (± SD) 16.3 (± 5.86) sessions to complete the Test-training and the female marmosets needed on average (± SD) 16.75 (± 7.17) sessions. The marmosets' Test-training appears to be akin to the dogs' behavior. By contrast, the results of the Tests demonstrated that the marmosets' ability to reason by exclusion is more on the level of the pigeon's performance. However, one should be cautious and emphasize that the comparison concerns a small sample size of two monkeys and one pigeon. Although none of my subjects showed reasoning by exclusion, it is still possible that they possess this cognitive ability, and there are a variety of factors that may have impeded the mechanism underlying reasoning by exclusion. One candidate is attention.

Attention is of high relevance concerning concentration for memorizing stimuli and building associations between the stimulus and the reward. Attention could not be recorded and analyzed because of technical difficulties, but it was considered and observed. Although marmosets have a small attention span of around 6 sec. (Range and Huber 2007), motivation to work was sustained while performing on the touch-sensitive screen (for several minutes) in most of the individuals. The more the subjects had positive experience (food reward) the more they behaved attentively to the screen. Attention of the animals was demonstrated by sitting

continuously on the platform looking at the screen, hanging on the wire-mesh in front of the screen (which reduced the distance to the reward) or touching the stimuli consecutively. Additionally, some of the individuals responded quickly and continuously, which became apparent through, for example, eating and touching at the same time. They made no unnecessary breaks in-between the trials. However, if they made several consecutive errors, attention and motivation were reduced in some cases. One male monkey (LO) elegantly demonstrated this by jumping off the platform and flipping backwards after each incorrect trial. Nevertheless, it should be considered that attention differs between species, as well as between individuals, and maybe for that reason some individuals (for example FI) had difficulty to distinguish and to memorize the stimuli.

More arguments speak against the possibility that marmosets are capable of reasoning by exclusion than in favor of it. However, failure of evidence is not necessarily evidence of a failure. Furthermore, some of my subjects showed a trend to reason by exclusion, as in some cases they significantly preferred novel stimuli over familiar ones (S-). But what was their incentive or purpose for choosing S´?

The outcome of the first test (Test 1a) showed that one subject (FI) had a propensity for the novel stimuli. If FI used reasoning by exclusion in Test 1a as a strategy then it would have performed differently in the second test (Test 2-Learning by exclusion). If reasoning was not controlling his behavior, he may perhaps have responded to novelty, i.e., the desire to explore new things (neophilia), and therefore was prevented from acquiring any information about the negative class-member (S-). For all other individuals, who significantly preferred the negative class-members, it can be concluded that they responded by avoidance (neophobia) or, more accurately, that they avoided novel things and thus chose the familiar stimuli. This occurred despite the familiar stimulus being S- and thus unrewarded. Furthermore, although none of those stimuli (S- or S´) were rewarded during test trials, S- may have been associated with food reward. An association could be deduced from the fact that S-/S+ trials always resulted in food reward, while S-/S´ trials never provided food reward.

Nevertheless, for animals that acted in a neophobic manner to S´, the repeated presentation of S´ did improve familiarization and therefore should devalue the novelty factor. Consequently, this would account for an increase of S´ choices from the first to the second cycle. Unfortunately, none of the subjects increased their choice preference in Test 1a-Choosing by exclusion for S´ from cycle 1 to cycle 2. Actually, FI showed the opposite, a high propensity to choose the novel stimuli in the beginning (second session of the first cycle with 100% choice preference), which

decreased from the first to the second cycle. Likewise, two other individuals (JAC, PA) had a complete choice preference for novel stimuli in the first session of the first cycle, but this preference was lost, as well. Spontaneous choice preference for S´ in the first cycle would fulfill the reasoning by exclusion criterion, because at the beginning of testing (first and second session) the animals would have had little experience with non-rewarded trials and the lack of reward should therefore not have biased their behavioral strategies.

After first and second session, subjects began to choose S´ or S- occasionally without a strong preference for either, as if they were trying to find the error in the procedure. It seemed that those subjects, who started with a propensity for the novel stimuli and lost it after merely two sessions (see Fig. 14, PA, JAC and FI), initially understood the logic behind the test paradigm. They chose the novel stimuli spontaneously (right away in the beginning), but this initial choice preference was not maintained in the course of further sessions. The more the subjects acquired experience with test trials the more their spontaneous behavior appeared to be influenced by a lack of reward. Their choice and motivation may have suffered/seemed to suffer from extended tests, since animals started to take breaks or even stopped working and had to be excluded from the test, for example ME. Despite this, the results of the first test cannot rule out the use of novelty as the discriminative factor.

The monkeys' behavior may not be surprising, since the task of a two-choice procedure was acquired through trial and error learning and consequently the animals may perceive unrewarded trials as errors. It is clear from the training procedure that they were able to learn on the basis of the food reward. This possibly accounted for their behavior, resulting in random choices on the test trials. Pavlov (1927) made an interesting observation regarding the method of experimentation: "When a positive conditioned stimulus is firmly established in a dog by means of the usual repetitions with reinforcement. A new stimulus is now occasionally added, and whenever the combination is applied, which may be at intervals sometimes extending to hours or days, it is never accompanied by the unconditioned stimulus. In this way the combination is gradually rendered ineffective, so that the conditioned stimulus when applied in combination with the additional stimulus loses its positive effect, although when applied singly and with constant reinforcement it retains its full powers". The monkeys may have shown behavior similar to that observed by Pavlov, since in S´/S- trials the conditioned S- seemed to lose its negative effect and was chosen by chance, although it was hardly ever selected in S+/S- trials. Further, Pearce and Hall and Pearce (1979) tested rats in an AB compound experiment in which

stimulus A was rewarded constantly. When it was presented in conjunction with another stimulus B (as a compound AB) and reward was absent, then B become a conditioned inhibitor for A. If S´ had an inhibitory effect for S- so that the negative class member was lost, then the animals had become habituated to those situations where reward differs with the learned associations, before testing the animals again. Therefore, I presented the marmosets with Extra training to enhance the consequence of negative stimuli. To facilitate learning, I reduced the possible numbers of negative stimuli from four to just one S-, which was later reused as the only negative stimulus in the following Extra test´. Unfortunately, the Extra training´ effort remained unsuccessful, probably due to the problem of selecting by chance in test trials. Consequently, the bias that may be caused by unrewarded test trials still existed and continued into another more specific training - Partial reward training. "Partial reinforcement refers to any schedule in which there is less than 100% contingency so there are instances when the animals' behavior is not reinforced" (Sangha et al. 2002).

According to the Pearce-Hall model (Bouton and Sunsay, 2001), a partial reward schedule should maintain attention because of the "surprise effect", where it cannot be anticipated when reinforcement occurs, which then strengthens attention and results in a stronger long-term memory effect. Greater attention increases association strength and thus allows memory to be more persistent (Sangha et al. 2002).

If a learned association about the negative class lost its effectiveness in conjunction with S´, one may assume that an unconditioned stimulus, like S´, would be only effective if it is not predicted or "surprising" (Pearce and Hall 1980).

The different conditions of reinforcement in the Partial reward training caused no difficulty to the subjects, except for FI, who was excluded from further procedures after failing in the 42nd session of the second condition (70% food reward). This was a very poor performance in comparison to the other subjects, who needed at maximum 5 to 6 sessions. In contrast to the theses of Sangha et al. (2002), but in line with the Pearce-Hall model, partial reinforcement decreased FI's attention. In all probability, he expected food constantly and non-rewarded trials may have generated an emotional state of frustration (Amsel 1958), resulting in low attention and poor performance.

The repetition of the Test 1b-Choosing by exclusion showed a significant increase in WI's and PA's performance, suggesting that lack of reinforcement on the previous test trials may have negatively affected performance. For SP and the other subjects, choice performance was similar to the results in Test 1a-Choosing by

exclusion. SP, for example, maintained a preference for S- throughout all tests, which could be due to the fact that she performed neophobically or avoided S´. The later may be due to a "blocking effect". This means that she would avoid (block) a stimulus type that was associated with the lack of reinforcement. This blocking effect may have already occurred after the first trial where no reinforcement was given (Mackintosh 1975). Consequently, all novel stimuli would be avoided by her in subsequent test trials.

The results of the second test, Test 2-Learning by exclusion, suggested that those animals who preferred S´ in the first test, did not apply reasoning by exclusion as the underlying strategy for solving the test trials. As discussed before, certain other factors could lead to the choice of S´ in the initial test other than reasoning by exclusion.

One further interpretation why the marmosets failed to show the ability to reason by exclusion could be that the animals avoided the negative class (S-) yet without acquiring any information about S´, and thus were unable to define it as a stimulus from the positive class. An alternative explanation in terms of neophilic behavior could be discounted, because the marmosets would have also displayed a great preference for S´´ in Test 2-Learning by exclusion. On the one hand, Aust et al. (2008) discuss the fact that those animals that showed evidence for reasoning by exclusion needed comparatively more training than the other subjects. This might only be the case for FI, who needed more training than all others and later showed a trend to infer reasoning by exclusion; unfortunately, he had to be excluded from further tests. On the other hand, WI and PA needed comparatively less training than the other subjects, and achieved significant results in Test 1b-Choosing by exclusion.

In conclusion, this study shows that the marmoset monkeys have the cognitive skills to learn a discriminative task in a touch-screen context. Therefore, I surmise that the main problem preventing them from achieving more advanced performances in such experiments is the sudden insertion of unrewarded test trials. It is possible that the animals were not flexible enough to switch from training trials (S+/S-) to test trials. The unrewarded test situation was indeed in strong contrast to training trials. However, the reason for conducting the no-food-reward-paradigm in test trials was necessary, since we could not condition the animals to the novel stimuli. In sum, it is not clear if the animals deduced positive class membership when choosing S´ (Test 1a/b-Choosing by exclusion) by excluding the negative alternatives. Nonetheless, the methodology is suitable for future studies. The failure of a species (or an individual) to perform well on a particular test does not necessarily mean that the species lacks the ability for which it is supposedly being tested. Some, yet untested, combinations

may produce clear results in the future and show that marmosets can learn and reason by exclusion.

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