How Much Can You Remember?
Operative memory capacity as a mental stimulation in bottlenose dolphins (*Tursiops truncatus*)

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In recent years, with the research in the cognitive behavioral training, we know that short-term retention is present in marine mammals. But can our animals remember past events and task and reconstruct them in future scenarios, or is it something that only humans can do? Our animals can't verbalize the memory, so it is difficult to test this hypothesis.
The last three years we chose Maya the dolphin to create a cognitive stimulation program, the goal was memory and perception. The choice was not random, Maya repeats aberrant behaviors after training (regurgitation). The first stage of the program was to examine the operational memory and the behavioral retention capacity, the second stage included presenting the different color boards, the dolphin could retain in memory shaped tasks, the third, Maya had to retain on memory all this information until a future training session 48 hours later.
Methods to address the question of memory retention: (1) The attention as basic for memory exercises. (2) The redirection in case of wrong answers. (3) Diminished the use of secondary reinforcement to condition memory task by using exclusively primary reinforcement, reducing the anxiety involved in the mid-term task.
Maya remembered 18 different tasks which are elicited two days before, and the aberrant behaviors decreased to 95 %.
In conclusion, the stimulation of the operational memory is very useful for the mental stimulation of our animals, also we believe that this type of programs can help for extinguishing aberrant behavior typical of areas with a history of low mental stimulation.

Cetaceans have very high social structures, generally share with primates certain characteristics of social organization (Connor, Smolker, & Richards, 1992). As the primate, under human care the bottlenose dolphin (*Tursiops truncatus)* has around its agents that modify social and individual dynamics to satisfy needs. Food habits sex and other activities are affected by the controlled environment and then those habits can be examined on a comparative basis.

In 2016 Maya a bottlenose dolphin, female of uncertain age and that live in Adaland dolphin park in Turkey, regurgitated after all kinds of training sessions; medical, social, shows, dolphin therapy, interactive programs and even free food sessions (Fig.1).

Based on the park behavioral records we assume that this behavior was transmitted from one to one of the dolphins and started due to a previous training system that used time out as a continuous resource and repeatedly ended the sessions without primary reinforcement. The punishment can get to rid some behaviors, and it also led to the other problems (Ramirez, 1999), regurgitation by imitation has already been documented (Yeater and Kuczaj, 2010).

According to the past records, Maya imitated the other dolphins' regurgitation the new observations suggested, to her wait at the ending of the session to reproduce the behavior by herself. This can be a deferred imitation (Kuczaj and Yeatre, 2006). Learning through imitation provides a rapid means of modify existing behaviors and acquiring new ones (Fellner, Bauer, & Harley, 2016). Also, Yeater (2005) has documented the voluntary regurgitation within a group of dolphins under human care, can be maintaining reinforce by reproducing their own play item, regurgitation fish.

The park records anthropomorphized about this behavior, according to some data collection studies, anthropomorphize may suggest a confusion in the animal welfare state (Mangas, Racciatti, & Ferrari, 2017) the reports characteristics suggested a lack of deep observation was evident.

It seemed that the regurgitation reinforced the animal, we assume this for four reasons: (1) It was repeated when the primary reinforcement offers ended. (2) It was maintained even when the trainer was removed from the environment. (3) Intensity increased when secondary reinforcement was used. (4) Intensity increased when negative reinforcement was used, and motivation decreased.

Apparently, Maya didn't find gratification in regular training challenges. This hypothesis implies the original pattern of behavior associate's regurgitation with the gratification, when a conditioning reflex is confirmed by experience, in fact enters a whole schema, ceases to be isolating and becomes an integral part of a real totally. It no longer a simple reflex to leading to satisfaction, this satisfaction becomes the essential (Piaget 1952).

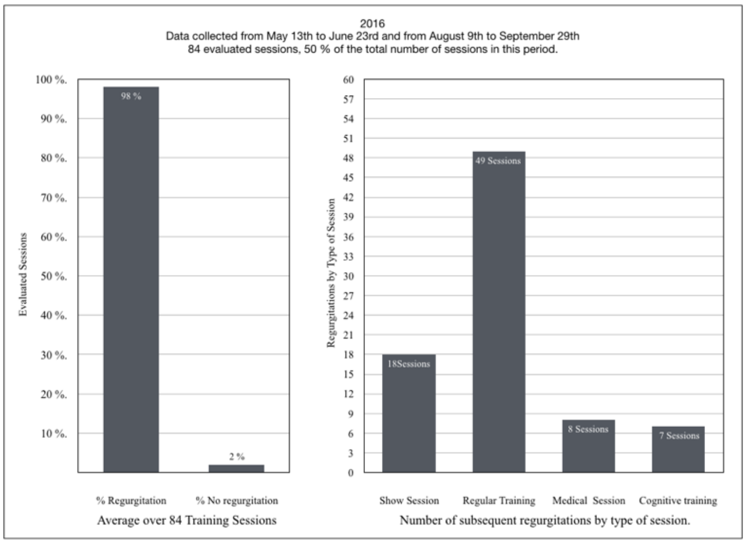

Fig.1

We choice Maya for a new training program that could maintain state of motivation and satisfaction after sessions by making training was rewarding on this own.

Stage I.

The training plan goal was to activate Maya working memory as a training driver. Generally, when talking about operative memory or working memory is in reference to the brain system that temporarily retains and manipulates the information necessary to perform a complex cognitive task such as learning, reasoning or understanding language (Baddeley, 1992). The difference between short- term memory and the operative are due to the attentional control that is directly involved in cognitive processing (Engle and Kane, 2004).

The dolphin was housed together two young males in sea water tank 18 m in diameter and 6 m deep. She was fed approximately in each cognitive training session by one-quarter of its daily ration of 10.5 kg average of capelin (*Mallotus villosus*). Maya never had been subjected a cognitive training.

1.1 The Mark Behavior.

When separates concepts are put together for the first time to form a new behavior, this is considerate abstract learning (Ramirez, 1999). Mark behavior consists of an abstract rule to keep a previously conditioning behavior in memory and to perform it a time later during the same training session following the corresponding mark SD (Ruiz, & Henderson, 2018).

Methods.

The mark behavior SD is to point to the dolphin with the index finger and the arms extended in direction of the dolphin face, followed by the SD of the behavior to remember, later touching fists against each other in front of the dolphin will indicate in the future the moment when the mark behavior will remember and perform, we will call it; go SD. E.g., the sequence is: Mark behavior SD + Turn Dance SD + Session continues + Mark behavior SD + Go SD + Dolphin performs the Turn Dance behavior (Fig.2).

Results.

After Maya learning the new SD concept, generalization of this rule was tested by presenting to Maya the combination between Mark behavior rules and nine behaviors she had ready conditioning (Table 1). At the beginning Maya sparingly achieved more than two mark behaviors, she tended to repeat the las previous performance behavior, after a training period the performance was very satisfactory. The dolphin chose the right behavior at levels above chance, showing that she could keep the behavior in memory during an extended period of time.

1.2 Image SD discrimination.

As the training plan broad consider Maya receptive competencies, we created plastics boards of 35 cm wide by 45 cm high with a printed symbol, the complete set of images created was fourteen different boards.

Methods.

Usually, in dolphins, a trained behavior is considered from the perspective detection of a simple gestural command. We had an SD optimality theory; after desensitizing the new material, we would try a memory task with a new SD, and these would replace the traditional hand signal SD with images printed on the board and that represents a previous conditioning behavior. During the session for a few seconds, we presented in front of Maya a board SD and later used a Go SD, Maya would to analyze the image and relate it to a specific behavior, e.g., the black line square board means for Maya to perform the beaching.

Results.

Training Maya in this kind of responses seemed to us an interesting cognitive analogy, because the success might depend on the dolphin decisional mechanism, Maya proved to be able discriminated a wide variety of behaviors analyzing the images on the board (Table 2).

1.3 Combination of two abstract concepts.

Mixed a two cognitive task demand a dolphin to categorize concepts, follow two abstract rules, build complex concepts and find the way to solve the problem (Ruiz, & Henderson, 2018).

Methods.

We trained Maya to perform a mark behavior with the images that represent behaviors, the previous nine behaviors that Maya related in board SD, could be reproduced in the abstract concept of mark behavior, e.g. The sequences may be; Mark behavior SD + Spinner jump SD/Blue star board + session continues + Mark behavior SD + Go SD + Dolphins performs the spinner jump (Fig 3).

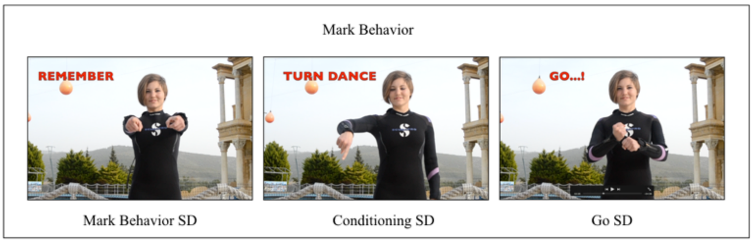

Fig. 2

Results.

Generalization of these combination concepts was tested by presenting to Maya with all possible comparisons between images boards SD. With more training time the dolphin made the right behavior at levels far above chance, showing that she could remember the symbols SD Included in mark behavior training dynamics.

Fig. 3

In this point the training sessions were longer than before, for keeping the attention during a long period we condition the continue-SD; two hands in front of the dolphin with palms open, this indicates to Maya that is doing well, but that the behaviors is not yet complete (Ramirez, 1999).

Behaviors Conditioning on Mark Behaviors SD

1	Jumps
2	Backwards Jumps
3	Spinner Jump
4	Fast Swim
5	Tail Wave
6	Turn Dance
7	Beaching
8	Clapping
9	Tail Splash
10	Singing
11	Pectoral Wave

Table 1

Behaviors Converted to Board Symbols SD

	Mark Behavior	Board Symbol SD
1	Jumps	Green Triangle
2	Backwards Jumps	White star into Red Circle
3	Spinner Jump	Blue Star
4	Fast Swim	Black Rhumbos
5	Tail Wave	Black Circle with Dot
6	Turn Dance	Blue Square
7	Beaching	Black Line Square
8	Clapping	Green Cross
9	Tail Spalsh	Red Square

Table 2

Stage II

2.1 Board Discrimination.

Usually, the dolphin training develops experiences through simple cognitive challenges required under human care, the advance cognitive training may reveal a capability that a species does not use in the wild. Previous works with marine animals at the Kewalo Basin Marine Mammal Lab. (Herman, 1986, 1987;Herman, Richards, & Wolz, 1984) At the Living Seas, EPCOT Center (Xitco, Gory, & Kucsaj,1991) at Disney's The Seas (Harley, Fellner, & Stamper, 2010) at Sky Dubai (Cuevas & Svensson, 2015) and National Aquarium Baltimore (Martin, 2015) provides evidence that marine mammals can learn a symbol system by operant conditioning using the matching learning or the sequential training.

Methods.

Although the whole set of images was fourteen, at the beginning only work with three, Maya discriminated between two different boards, once she understands the concept we increased the number of images to discriminate in four secondary colors according to the subtractive model; black, blue, green and red (Fig. 4).

To generate the phenomenon of subtractive color, it is necessary to have a light source, a support and pigment. It is ideal that the support be with so that it can more easily transmit the luminosity that is being sought (Castañeda, 2005).

We chose those colors considering humans the color is related to the light and the way it is reflected. We know that studies in bottlenose dolphins on visual color perception and processing behavior are complicated, because it has not yet been determined whether the species responds primarily to color vs brightness (Griebel and Peichi, 2003; Levinson and Dizon, 2003).

For training, we show the dolphin two primary discrimination boards; one without symbol, one with a symbol and a way easy to election the correct one, touch with the top of the nose the correct one, the boards from which she had to discriminate was held by a trainer who stood immediately adjacent to the tank wall (Fig. 5).

Results.

Generalization of this abstract rule was improving by presenting to Maya with all the possible pairwise comparations between boards, at the beginning Maya sparingly achieved the most difficult trials, near to the end of 2017 the performance was perfect. The dolphin chose the correct boards at levels far above chance, showing that she could discriminate form and color between different boards. By the middle of 2017, the regurgitation decreased in 40 % of the total number of the sessions (Fig. 6).

At the moment of ending the stage II of the training, the dolphin was fed approximately in each cognitive training session by one-fifth of its daily ration of 8.5 kg average of capelin and 0.5 kg of Atlantic mackerel (*Scomber scombrus*).

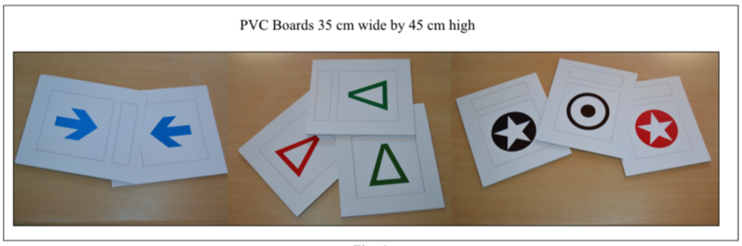

Fig. 4

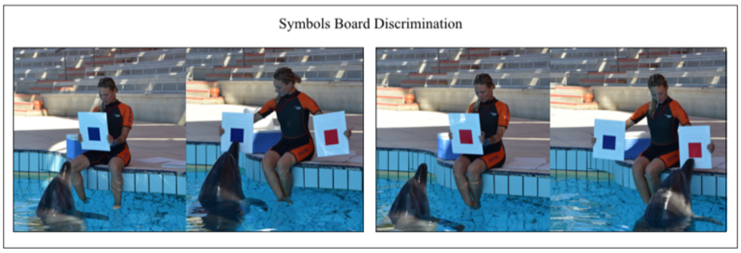

Fig. 5

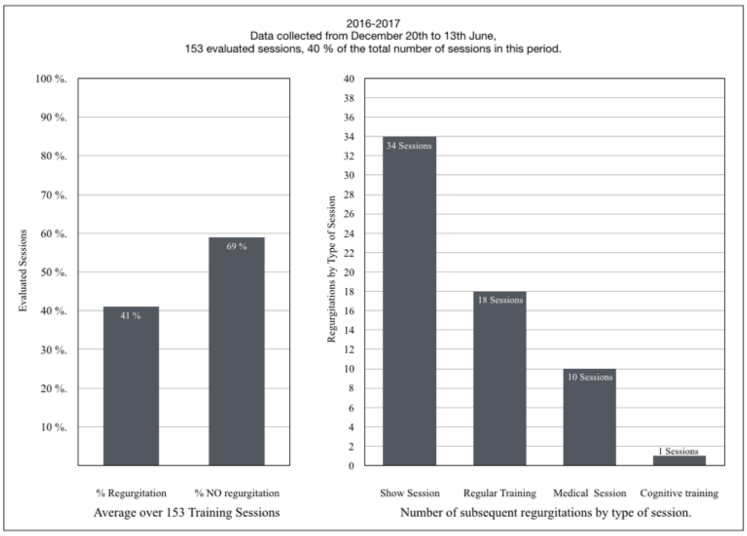

Fig. 6

2.2 Behavior Redirection

The humans can't ask the dolphins, "what should you do?", "when should we do?"," What will we do?". We propose a proactive model to develop dolphin communication skills. The trainer facilitates the learning interaction by making the dolphin understand that the mistake is allowed, and the success will be reinforced by a better option, we call this; behavioral redirection.

A trainer must ignore the incorrect behavior, use the Least Reinforcing Scenario/Stimulus (L.R.S.), later to add in the session other compatible behavior, following reinforce that behavior, indicate the appropriate behavior, finally, provide a reinforce rule to suggest why perform the correct behavior is better option. Thus, rule of reinforcement is the magnitude of primary reinforcement.

The redirection implementation also has been developed in other animals of the marine park.

Stage III

3.1 Categories of Memory SD.

The increased in the processing demand affect the capacity of retention (Daneman and Carpenter, 1980). To generate memory task with the abstract and visual concept learned, we create a set of gestural SDs, Maya then could categorize and remember a complex task.

Methods.

Those SD s (fig.7) indicates the order in which the tasks should be executed:

(1) Right hand raised.
(2) Left hand raised.
(3) Crossed arms.
(4) Right fist over the head.
(5) Left fist over the head.

Maya would respond to three specific SD within Mark Behavior concept:

(a) It indicates the mark behavior concept.
(b) It indicates with a gestural SD, the order in which the element should be performed.
(c) It indicates the behavior to remember.

Maya would also categorize those same SDs to remember board symbols:

(a) It indicates the symbol to remember.
(b) It indicates with the gestural SD, the order which that task should be performance.

For the memory test were not used behaviors that had not been formally tested previously and the program focused on Maya not find the way to simulate or chain the responses. We call a behavioral chain if a performance of behavior may cue the start of the next one, in the chain the subsequent behavior reinforces the previous one (Ramirez1999).

Results.

The generalization of this training model was based on two generals' positions using the trainer himself as a positional SD; (1) trainer on his or her knees for symbols. (2) Trainer stand up for the mark behavior performance. During the session the expectancies on the next trainer body position increased the positive performance probabilities by selective reinforcement each trainer position on each trail.

Gestural Memory Set SD Set

I. Raise a Left Hand — II. Raise a Right Hand

I. Crossed Arms — IV. Right Hand on the Head. — IV. Left Hand on the Head.

Fig.7

3.2 Morning to afternoon memory task.

We investigated whether Maya could recall actions we had morning solicited, remember and performance those recollections afternoon. The memory test was composed of two baselines: Mark behavior and symbols discrimination under the gestural memory SDs.

Methods.

The behaviors were grouped into memory task set of increasing complexity. The training set was composed of eight not sequential memory tasks to we ask to Maya retain and we recover in a training session at the same afternoon, between these sessions Maya made her normal daily schedule. Every day Maya perform one set different to the next day, repeating some, but not all of the task and increased the number task gradually until 18 actions to remember.

Results.

Maya performance levels overall were high, 99 %. She correctly remembered all morning-afternoon memory sets at 23 out of 25 trials between November 9, to December 22 of 2018. These results suggested to us that Maya can access a large number of memories actions, if the task set proposition is sufficient detail to allow for executions of behavior under abstract rules.

3.3 Memory testing to 48 hours.

Finally, we investigated whether Maya could recall actions she stored days before and performance those recollections in subsequent days, following the same baseline by gestural memory SDs.

Methods.

We chose sequence of 18 behaviors to remember in two stations, right and left to the trainers, the test must be recover more than 12 hours, Sundays we didn’t train, and every Monday of a new week changes the sequence and then extended the time for recovering recollections for 12 to 24 hours, 24 to 36 hours and 36 to 48 hours.

The behaviors were grouped at three complex test sets, sequential elements which if a behavior was complete, might cue perform the next one within sequence. The first set was composed by six mark behavior task and the last two sets were composed by 10 discriminations of symbols, the 18 elements should be recovering half set at right station and other half set at left station, 9 each one (Table 3).

Sequence and Grouping Table, Memory Test Set at 48 hours

Gurupo A Mark Behavior Task			Gurupo B, Shape Discrimination Task			Gurupo C Shape DiscriminationTask		
	Mark Behavior	Memory SD		Board Symbol	Memory SD		board Symbols	Memory SD
1	Tail Wave/Black Circle with Dot	Raise a Right Hand	1	Blue Arrow Direction Right	Fists Together	1	BluE Arrow Direction Left.	Fists Together
2	Turn Dance/Blue Square	Raise a Left Hand	2	White Star into Black Circle	Raise a Right Hand	2	Green Triangle	Raise a Right Hand
3	Jump/Green Triangle	Cross Hands	3	Red Triangle	Raise a Left Hand	3	Black Circle with Dot	Raise a Left Hand
4	Fast Swim/Black Rhumbos	Right Hand on the Head	4	Geen Cross	Cross Hands	4	Blue Star	Cross Hands
5	Spinner Jump/ Blue Star	Left Hand on the Head	5	Blue Square	Right Hand on the Head	5	Red Square	Right Hand on the Head
6	Backwards Jumps/White Star into Red Circle	Two Hands on the Head	6	Backwards Jumps/White star into Red Circle	Left Hand on the Head	6	Black Line Square	Left Hand on the Head

Table 3

Results.

In this challenge, Maya has above-chance levels; she was 100% correct on 9 out of 12 initial 24 hours trials, 75 %. And 9 out of 10 48 hours trials 90 %, tested during the five initials months of 2019. Based in the sequence learning, we assume that Maya can access by long term memory from all the actions stored since a set proposition training session to the next 48 hours, responding serially regardless the concepts involving in the test or the activities she had during the course of those 48 hours.

Discussion.

Although one of the training concepts teaches to Maya don't have an entirely scientific rigor, because the trainer factor was not subtracted in the image board discrimination, the patter of regurgitation recurrence is consistent with the idea that the motivation of this model training, can maintain the aberrant behavior suppressing after ending the session (Fig. 8).

This training explore no only the physical and mental skills, also the confidence matter; focusing in reinforce self-efficacy in new training challenges, and give confidence by tools such a behavioral redirection, may reduce the level of anxiety can dolphin feel with the failure situations and also self-reinforce the effectiveness as move forward within the learning.

On the other hand, the discipline required for the cognitive test by the trainer must be higher than normal, because the animal has proved can find the way to the simulation to solve a memory problem. The proposal is to generate significant knowledge in this type of training, by having failures of expectations (Galagovsky, 1996) and return to the beginning of the sequence, so, that the concepts are firmly conditioning in the animal.

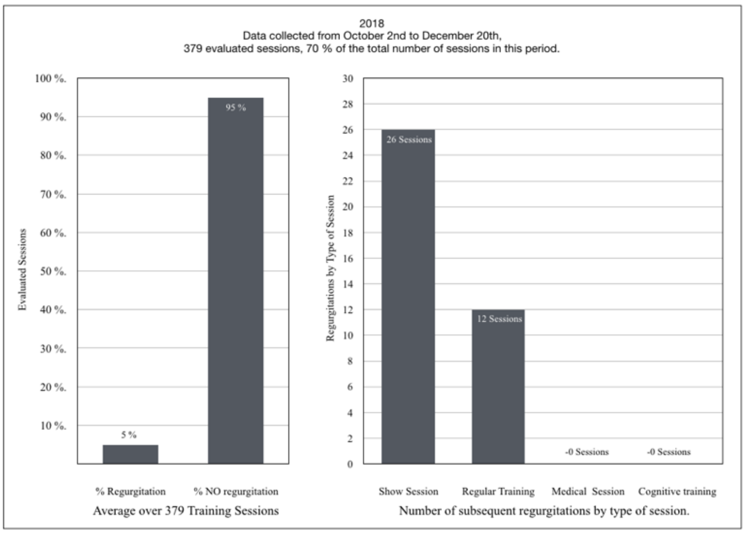

Fig. 8

However, when the Maya failed, it was without a defined pattern and although we can't say that the daily schedule modified the goal of the training plan, neither could we reproduce exactly the same conditions in each of the memory session during the three years of this training program.

Conclusion.

Currently, we don't have a theory adequate to describe sequential learning phenomena of Maya, although our final assessment of effects this training program was beyond than initials expectations.

As the dolphin was tested only increasing the complexity of the memory sets, we assumed that the dolphin skills were improving as training advanced. The stimulation of the operational memory seems to be very useful for the animal mental stimulation, also, we believe that this type of training, although long can help for extinguishing aberrant behaviors typical of areas with a history of low mental stimulation, the whole program achieved the planned goal: Decreasing the regurgitation until almost disappearing (Fig. 9).

All this leads to the reflection that training in the cognitive processes should be considered as a learning opportunity and not as a simple and different training achievement.

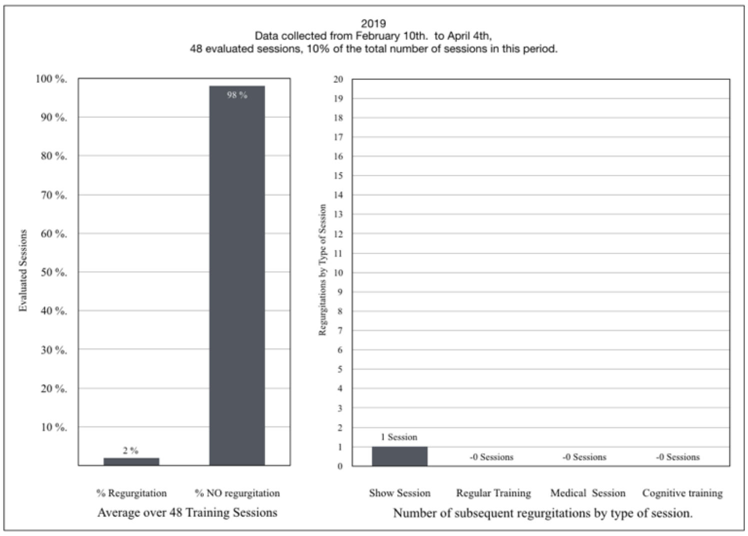

Fig. 9

Supplementary Materials.
Supplementary video material for this article available at
(https://www.youtube.com/watch?v=yVGBo6TDfyU&t=194s
Supplementary Methods.
Table 1. Data resulting training (1.1): Mark behavior in relation to previous conditioning behaviors.
Table 2. Data resulting training (1.2): Board symbols SD in relation to with the Mark behaviors conditioning.
Table 3. Sequential memory test at 48 hours (3.3).
Fig. 1. Data source of sessions with regurgitation, 2016.
Fig. 2. Mark behavior SD delivery sequence. (1.1).
Fig. 3. Mark behavior board SD delivery sequence (1.3).
Fig. 4. Training material (2.1).
Fig. 5. Board symbols discrimination example. (2.1).
Fig. 6. Data source of sessions with regurgitation, 2016-2017(2.1).
Fig. 7. Categories of Memory SD, 3.1.
Fig. 8. Data source of sessions with regurgitation, 2018.
Fig. 9. Data source of sessions with regurgitation, 2019.

Competing interest:
The authors declare that they have no competing interests.
Ethics statement:
The procedure for the training followed the guidelines for research using zoo-based animals of the code of ethics and welfare by zoos and aquariums issued by the World Association of Zoos and Aquariums WAZA.
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To Salvador.