Investigation of cognitive enrichment training's impact on dolphin behavior patterns

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1 Introduction

Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) live in a highly connected societies with fission-fusion pattern, that is, although the group-subgroup-individual hierarchy remains relatively stable, the composition of tiny social structures as triads or dyads are highly interchangeable in a daily or hourly basis (Leatherwood & Reeves, 2012). Factors that may be involved in forming relationships between individuals are gender, age, kinship, temporal status and personality (Highfill & Kuczaj, 2007; Walker, Miller, Kuczaj, & Solangi, 2017). Wild bottlenose dolphins are presented widely across the low-middle latitude regions within varying group sizes from 2 to 10000 individuals. Due to their wide distribution and the variety of habitats they occupy their social structure shows high variability. Important behaviors of bottlenose dolphins include long-distance traveling (Shirakihara & Miki, 2012), during which specific cooperation between male dolphins are fundamental (Connor, Smolker, & Richards, 1992; Randić, Connor, Sherwin, & Krützen, 2012). Alliances between males may consist of stable trios and pairs (first-order alliances) to herd female dolphins. These trios or pairs then might engage in creating second-order alliances in contests over females against other males (Connor and Krützen 2015). Pro-social and agonistic behaviors are both part of the dolphins' natural behavior repertoire. Investigation of their function and use in group living can provide important keys to the understanding of dolphin societies. Affiliative behaviors may exhibit through physical contact (Dudzinski, Thomas, & Douaze, 2009), synchronous swim (Clegg, Rödel, & Delfour, 2017) and play behaviors (S. A. Kuczaj & Eskelinen, 2014; S. A. Kuczaj, Ii & Walker, 2012). Previous research suggests that at least some dolphins have preferred partners with whom they exchange contact (Randić et al.,

2012). Research studies have shown that although in infant stage, connections between individuals (mostly in calf-mother relationship) are majorly direct physical contact, after six weeks of birth, synchronous breathing, swimming and playing without contact become dominant (Connor, Smolker, & Bejder, 2006). Synchronous behavior, defined to describe two or more animals perform the same behavior at the same time span, is considered to be served an important role in associations among bottlenose dolphins (Fellner, Bauer, Stamper, Losch, & Dahood, 2013). Synchronous breathing and swimming, for instance, has been described qualitatively within a range of contexts (Fellner, Bauer, & Harley, 2006). Several researchers have noted synchronous swimming as a fear action in respond to predators or novel objects, mother-calf learning behaviors or mating encounters (Hastie, Wilson, Tufft, & Thompson, 2003; Sakai, Morisaka, Kogi, Hishii, & Kohshima, 2010). Synchrony is also evident during play episodes and coordinated hunting efforts (Connor et al., 2006; S. A. Kuczaj, Ii & Walker, 2012).

Due to the natural limitation of observation chances, the behaviors cannot be recorded precisely (Wells, 2003). However, studies on bottlenose dolphins under human care allow more precise, fine-scale social behavioral data collection (Lopez Marulanda, Adam, & Delfour, 2016; Miller et al., 2015). Well-recorded data can help better understanding the social and behavioral patterns of dolphins under professional care and can help maintain positive well-being. One common method to promote both physiological and psychological welfare of bottlenose dolphins is using environmental enrichment devices (EEDs) (Hoy, Murray, & Tribe, 2010). EEDs are categorized by their function such as visual, auditory, olfactory, etc. Among these, Cognitive enrichment devices as a novel type of EEDs, have been reported to promote positive well-being and also offer opportunities to the subjects to practice their cognitive and problem-solving skills (Fellner et al., 2013).

This study measures the direct impact of a use of a novel cognitive enrichment device on a male social group using a behavioral ethogram. An ethogram is a catalogue of

behaviors exhibited by animals, where these behaviors are hierarchical and exclusive to each other. Researchers can have their observation records documented accordingly, therefore it is proposed as a standardized tool for ethological field work on dolphins (Muller, Boutiere, Weaver, & Candelon, 1998).

Generally, two approaches can be applied to determine the social connections: By observing the occurrence and frequency of special social behaviors (pectoral fin contact), or by measuring the time individuals spend together (Connor et al., 1992; New et al., 2013). Recent studies have investigated daily activities in small groups of bottlenose dolphins under professional care (aquariums and marine parks, for instance), and to determine whether an alternative behavior pattern occurred from those in wild environment (S. A. Kuczaj & Eskelinen, 2014; New et al., 2013). They found that, for instance, play signals of dolphins are rare to be observed but common in those under professional care, probably due to toys provided. However, to date, few studies have focused on the influence of training sessions on dolphins' behavioral pattern.

This study investigated the potential behavior changes in four male bottlenose dolphins, as a result of temporary access to a novel cognitive enrichment device and regular enrichment devices. By comparing the dolphins' behavior in pre- and post-session, the analysis focused on the potential changes in stationary and swimming behaviors, play behaviors and social behaviors in overall and individual scale.

2 Materials and Method

2.1 Facilities

The experiment was conducted in one of the two dolphin facilities in Ocean Park Hong Kong (OPHK); Ocean Theatre (OT). OT had six interconnecting pools, the experiment was carried out in pool 1 and 2 (session 1-6), and in pool 3 and 4 (sessions 7-10). The

pools were oval shaped, 15.0 m x 7.9 m in diameter and 4.0 m deep.

2.2 Subjects

A group of four adult male Indo-Pacific Bottlenose dolphins (*Tursiops aduncus*) participated in the tests (Table 1). Before this experiment, none of these dolphins had any prior experience with the cognitive enrichment devices used in this test. Besides participating in the research sessions, the dolphins were also involved in educational programs and daily presentations.

TABLE 1 Basic information of bottlenose dolphin subjects at the time of experiment

Name	Age	Origin	Relationship
Angelo	5	Ocean Park, Hong Kong	Half-brother of Anson and Toto
Anson	12	Ocean Park, Hong Kong	Half-brother of Angelo and Toto
Ginsan	12	Ocean Park, Hong Kong	No relation
Toto	21	Ocean Park, Hong Kong	Half-brother of Angelo and Anson

2.3 Equipment

The cognitive enrichment device was designed to model cooperative social behaviors in a dolphin groups, providing opportunities for cooperative food sharing (Kuczaj et al. 2015; Matrai et al. 2020). This study did not focus on the use of the cognitive enrichment device, instead only on the pre- and post-session periods, before and after the device was available to the dolphins.

The video data collection was conducted using two GoPro cameras (HERO4 silver) attached to custom-made holders suspended underwater, and one in-air handhold camera (Sony FDR-AX100 4K Handycam).

2.4 Procedure

The 10 sessions of data collection took place between 10th November, 2016 and 13rd December, 2016. Experimental sessions were conducted twice a week during the

dolphins' free-swimming time, between feeding sessions. The dolphins did not receive any specific training regarding the use of the cognitive enrichment; instead focusing on their innate ability of problem solving, as well as trial and error and observational learning.

The session was conducted in three parts: 1) Two-minute pre-session observation – after the completion of setting up the recording devices the dolphins were allowed to swim freely for two minutes with no access to any enrichment devices; 2) Fifteen-minute training session – the dolphins had free access to the cognitive enrichment device; and 3) Two-minute post-session observation – following the removal of the cognitive enrichment device, the dolphins were provided with regular enrichment items and observed for an additional two minutes.

This study focused on the analysis and comparison of the pre- and post-session observations.

2.5 Data analysis

In the ethogram the behaviors were divided into three main categories: Stationary and swimming behaviors, Play behaviors and Social behaviors (Table 2). These behaviors were divided into two categories: Discrete behaviors that usually lasts less than 1 second were categorized as point event, and others as continuous activity were categorized as state event. The original video data was coded using free-access BORIS software (Friard & Gamba, 2016) with respect to the ethogram. Each video was assigned to two researchers to complete coding individually, then the result was compared using Kohen's kappa method. The method was embedded in BORIS software, and only when the value was higher than 0.6 (shows good inter-rater reliability) can the results be used for analysis. Then the results were exported in csv format, and randomly picked in one of two researchers' work. Then the data was processed using NumPy (version 1.12.0) and pandas (version 0.20.3) in Python (version 3.7.3), and analyzed the frequency (for point events) and time duration (for state events) of each behavior in all sections in Microsoft Excel (2013). Total duration and frequency of each behavior

was conducted, and the differences between pre- and post-sessions were made in percentage. To make comparisons of all behaviors to each pair of subjects, pairwise T-test was performed, using p = 0.05 as significance level. Then for each behavior, Wilcoxon Signed Rank test was performed to each pair of subjects, using p = 0.05 as significance level.

TABLE 2 Behavior ethogram used for behavioral coding containing the 18 observed behavioral units grouped in three main categories references indicating the origin of the description; OP indicates that the descriptions were created by the research team of Ocean park.

Category	Behavior	Definition	Reference
Stationary and swimming behavior rs	Swim	Regular and continuous swimming with normal direction	OP
	Side swim	Forward progress with an angle of rotation of more than 45 degrees from the dorsal position up to 90 degrees from the dorsal position, orienting one pectoral fin upward and the other downward	(Miles & Herzing, 2003)
	Drifting	Stay at surface without active swimming	OP
	Belly-up swim	Forward progress with the belly facing upwards at an angle greater than 90 degrees from the dorsal position	(Muller et al., 1998)
	Stationary observation of the poolside	stays at the same location at the poolside observing the activities from above the water.	OP
	Leaning on the poolside	The dolphin places all of their head onto the poolside for at least 3 seconds, seeming to be observing poolside activities	OP
	Investigation of the underwater camera	The dolphins look closely and inspects the camera without touching it.	OP
	head up swimming	Orient the head out of water and move forward, clearing the surface in dorsal position, observing the poolside as the dolphin swims along	(Xian, Wang, Jiang, Zheng, & Wang, 2010)
	Spy hop*	Breif vertical or near vertical elevation of the body and head up exposure of the fore section follow by a sinking return to the water	(Muller et al., 1998)

	Scanning the pool wall	The dolphin appears to stare at the wall keeping the same location or slowly moving along the wall.	OP
	Regurgitation*	The dolphin brings its previously swallowed food back into his mouth or throat. Recognized by either seeing a whole fish reappear in the mouth or a lump in the throat.	OP
Play behaviors	Play with a toy	Transporting an object by using the outside of the beak, the flippers or the melon, passing and slightly touching an object, balancing/dribbling/catching/throwing and catching/pushing or pulling an object whit the beak, pressing it under water /rolling it on the ground by using the beak or the body and holding it in the beak while swimming for at least 2 seconds.	OP
	Bubble blowing*	A single large bubble from the blowhole	OP
	Leap / Jump*	Entire Body clears the water (any Height). Exit and enter head first with venter/dorsum/side facing down, little water displacement.	(Shane, 1990)
	Investigation of a toy	The dolphin appears to stare at the toy keeping the same location or slowly moving along the toy.	(Clark & Smith, 2013)
Social behaviors	Cooperative play with a toy	Play with toys together with other dolphin(s) - pull/push	OP
	Synchronous swim	Two or more individuals swim together keeping the same speed and depth, resurface and breathe in the same rhythm	OP
	Observation of another dolphin interacting with a toy	One dolphin is observing the other's actions towards the toy	OP

Note: *point event; else state event

3 Results

3.1 Duration

The four dolphins' behaviors over the 10 pre- and post-sessions were compared. Out of

18 behaviors, 11 (8 state and 3 point) were observed during both pre- and post-sessions. The behavior related to swim (swim, side swim, head up swim and belly up swim) consisted the major part of the dolphins' activity (Table 3).

TABLE 3 Total duration (state event) in seconds or frequency (point event) in count of each behavior during the 10 pre- and post-sessions.

Category	Behavior	Pre-session	Post-session
Stationary and swimming behavior	Swim	1930.377	1861.521
	Side swim	265.888	323.954
	Head up swim	326.466	289.967
	Stationary observation of poolside	1400.854	1063.005
	Belly up swim	555.978	622.949
	Leaning on the poolside	36.155	39.074
	Scanning the poolwall	4.17	220.664
	Drifting	101.023	13.547
	Investigation of the underwater camera	3.754	0
	Regurgitation*	90	65
	Spy hop*	31	55
Play behavior	Play with object/toy	0	332.201
	Investigation of a toy	0	16.67
	Bubble blowing*	1	7
	Leap/jump*	0	1
Social behavior	Cooperative play with a toy	0	157.44
	Synchronous swim	114.622	0
	Observation of another dolphin interaction with a toy	0	29.944

Note: *point event; else state event.

No difference was found in the relative duration of six state behaviors (swim, side swim, head up swim, stationary observation of poolside, belly up swim and leaning on the poolside) between the pre- and post-session conditions (Table 4).

When analyzing the behavior categories separately, dolphins spent majority of their time on swimming and the difference is not significant between pre- (41.23%) and post-session (37.98%) conditions (Table 4 and Figure 1). They engaged in stationary observation of poolside 29.92% of their time in pre-sessions and 21.69% of their time in post-sessions without significant difference between the two conditions (Table 4 and

Figure 1).

When analyzing the eight state behaviors separately, two behaviors were found with significant difference between pre- and post-session conditions. ”Drifting” appreciable decreased in post-session (2.16% in pre-session versus 0.28% in post-session) and “Scanning the poolwall” increased in post session(0.09% in pre-session and 4.50% in post-session) (Table 4 and Figure 1).

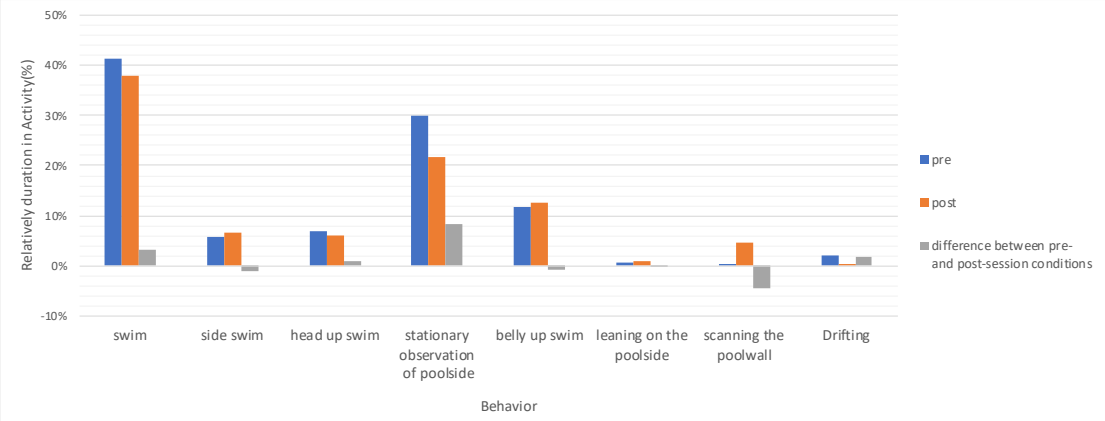

FIGURE 1 Relatively duration of each behavior (which were observed during both pre- and post-session) in pre- and post-session conditions.

In social behaviors analysis, since there was little data available, descriptive statistics were used rather than test statistics. Since there were no toys in the pool for pre-session, our dolphins only have cooperative play with a toy and observation of another dolphin interacting with a toy in post-session. Angelo was the most willing dolphin to have a cooperative play with another dolphin (Table 5). “Cooperative play with a toy” occurred for a total of 157.204s, with Angelo accounting for half of it. Angelo played toys with the other three dolphins respectively. Compared with the others, Toto and Ginsan relatively liked to observe another dolphin interacting with a toy, which can also be concluded from the data. In “Observation of another dolphin interaction with a toy” duration, Toto occupies 44.57% and Ginsan occupied 42.25% (Table 5).

TABLE 5 Total duration of Social behaviors events observed in 10 pre-and post-sessions with the details in specific session.

Category	Behavior	Pre-session	Post-session
Social behavior	Cooperative play with a toy_(Angelo-Toto) in 2 post-session	0	21.499
	Cooperative play with a toy_(Angelo-Anson) in 2 post-session	0	12.399
	Cooperative play with a toy_(Angelo-Ginsan) in 3 and 7 post-session	0	44.704
	Synchronous swim_(Angelo-Anson) in 6 pre-session	2.506	0
	Synchronous swim_(Toto-Anson) in 10 pre-session	54.805	0
	Observation of another dolphin interaction with a toy_ (Toto) in 6 and 7 post-session	0	17.341
	Observation of another dolphin interaction with a toy_(Ginsan) in 6 and 7 post-session	0	16.44
	Observation of another dolphin interaction with a toy_(Anson) in 5 post-session	0	5.13

3.2 Frequency

The comparison of the relative frequencies of the 3 behaviors showed significant difference between pre- and post-session conditions. Regurgitation happened 90 times in pre-session and 65 times in post-session. Dolphins had 31 times spy hop in pre-session and 55 times in post-session. They had one-time bubble blowing in pre-session and seven times in post-session (Table 4 and Figure 2).

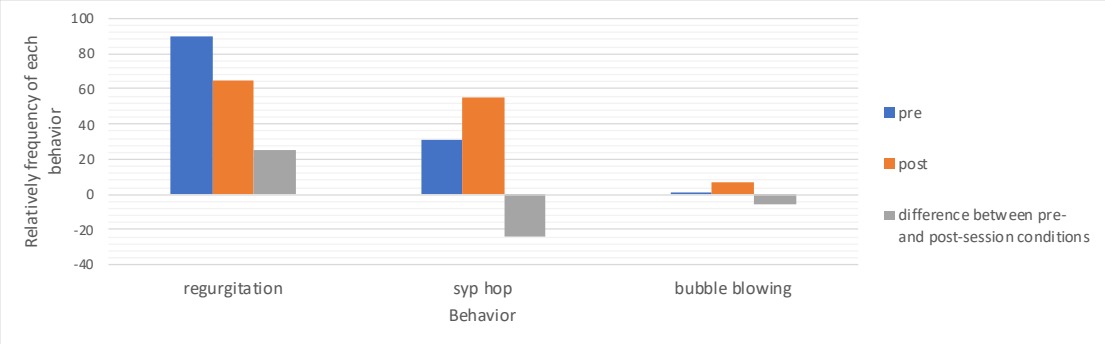

FIGURE 2 Relatively frequency of each behavior in pre- and post-session conditions

TABLE 4 Comparison of each behavior (which were observed during both pre- and post-session) between pre- and post-session conditions

Category	Behavior	T stat	P value

Stationary and swimming behaviors	Swim	445.0	0.3190
	Side swim	302.0	0.2276
	Head up swim	408.0	0.2933
	Stationary observation of the poolside	432.0	0.1862
	Belly up swim	326.0	0.3502
	Leaning on the poolside	25.0	0.8365
	Scanning the poolwall	84.5	.0292*
	Drifting	5.0	.0382*
	Regurgitation_(Point)	258.0	.0474*
	Spy hop_(Point)	84.5	.0292*
Play behavior	Bubble blowing_(Point)	3.0	.0478*

Note: T stats and P values are the results of a one-tailed, Wilcoxon Signed-Rank test. *p <.05.

3.3 Within condition comparison

The comparison of the dolphin behaviors during the pre-session and post session conditions separately showed no significant differences (Table 6).

TABLE 6 Comparison of the for dolphins' behaviors during pre- and post-session conditions separately

Pre pairs	T stat	P value	Post pairs	T stat	P value
Angelo-Toto	0.0443	0.9648	Angelo-Toto	-1.133	0.2599
Angelo-Ginsan	0.0103	0.9918	Angelo-Ginsan	-0.9079	0.3662
Angelo-Anson	-0.0163	0.987	Angelo-Anson	-0.1561	0.8763
Toto-Ginsan	0.0353	0.9719	Toto-Ginsan	0.2617	0.7941
Toto-Anson	0.0323	0.9743	Toto-Anson	1.1624	0.2479
Ginsan-Anson	-0.0057	0.9955	Ginsan-Anson	0.9014	0.3696

Note: *T* stat and *P* values are the result of a two-sided, T-test

From the five state behaviors three (Swim, Head up swim, Belly up swim) were showed individual differences between the four dolphins during the pre-session. During the pre-session, 'Swim' had significant difference in two dolphin pairs, 'Head up swim' had significant difference in two dolphin pairs and 'Belly up swim' had significant difference in two dolphin pairs (Table 7 and Table 8).

From the two point behaviors one (Regurgitation) were showed individual differences between the four dolphins during the pre-session. During the pre-session, 'Regurgitation' had significant difference in three dolphin pairs (Table 7 and Table 8).

Looking at the significant differences in specific behaviors between certain dolphin pairs in pre-session condition: significant differences were observed in “Swim” behavior between Angelo (51.60%) and Toto (29.90%), as well as between Toto (29.90%) and Ginsan (38.87%). Significant difference in “Belly up swim” behavior was observed between Angelo (3.65%) and Toto (18.20%), as well as between Angelo (3.65%) and Anson (15.88%). Significant difference in “Head up swim” behavior was observed between Angelo (7.77%) and Ginsan (3.18%), as well as between Toto (10.32%) and Ginsan (3.18%) (Table 7 and Table 8 and Figure 3). Significant difference in “Regurgitation” behavior was observed between Angelo (six times) and Ginsan (32 times), Angelo (6 times) and Anson (38 times), as well as between Toto (14 times) and Ginsan (32 times) (Table 7 and Table 8 and Figure 4).

From the five state behaviors three (Swim, Side swim, Belly up swim) were showed individual differences between the four dolphins during the post-session. During the post-session, ‘Swim’ had significant difference in two dolphin pairs, ‘Side swim’ had significant difference in four dolphin pairs and ‘Belly up swim’ had significant difference in three dolphin pairs (Table 7 and Table 8).

From the two point behaviors one (Regurgitation) were showed individual differences between the four dolphins during the post-session(Table 7 and Table 8).

Looking at the significant differences in specific behaviors between certain dolphin pairs in post-session condition: significant differences were observed in “Swim” behavior between Angelo (48.26%) and Anson (26.38%) , as well as between Ginsan (42.04%) and Anson (26.38%) . Significant difference in ‘Side Swim’ behavior was observed in between Angelo (1.39%) and Toto (11.25%), Angelo (1.39%) and Ginsan (10.75%), Toto (11.25%) and Anson (3.58%), as well as Ginsan (10.75%) and Anson (3.58%) . Significant difference in ‘Belly Up Swim’ behavior was observed in between Angelo (3.45%) and Toto (11.25%), Angelo (3.45%) and Ginsan (15.46%), as well as

Angelo (3.45%) and Anson (16.98%) (Table 7 and Table 8 and Figure 3). Significant difference in “Regurgitation” behavior was observed between Angelo (3 times) and Toto (10 times) , Angelo (3 times) and Anson (20 times) , Toto (10 times) and Ginsan (32 times) , as well as Ginsan (32 times) and Anson (20 times) (Table 7 and Table 8 and Figure 4).

TABLE 7 Pairwise comparison of the four dolphins activities including five state and two point events during pre-session and post-session conditions.

Difference between Angelo and Toto			**Difference between Angelo and Ginsan**			**Difference between Angelo and Anson**		
Swim	T stat	P value	Swim	T stat	P value	Swim	T stat	P value
pre session	8	*0.0469	pre session	6	0.0506	pre session	17	0.2845
post session	13	0.1394	post session	24	0.7213	post session	5	*0.0218
Side Swim	T stat	P value	Side Swim	T stat	P value	Side Swim	T stat	P value
pre session	7	0.2367	pre session	7	0.1235	pre session	7	0.0663
post session	1	**0.0069	post session	0	**0.0051	post session	7	0.1235
Belly up swim	T stat	P value	Belly up swim	T stat	P value	Belly up swim	T stat	P value
pre session	4	*0.0284	pre session	5	0.2489	pre session	1	*0.0109
post session	0	**0.0051	post session	3	*0.0209	post session	6	*0.0284
Stationary observation of the poolside	T stat	P value	Stationary observation of the poolside	T stat	P value	Stationary observation of the poolside	T stat	P value
pre session	26	0.8785	pre session	21	0.5076	pre session	22	0.5751
post session	12	0.4008	post session	22	0.9528	post session	9	0.1097
Head up swim post	T stat	P value	Head up swim post	T stat	P value	Head up swim post	T stat	P value
pre session	16	0.2411	pre session	3	*0.0357	pre session	25	0.7989
post session	17	0.2845	post session	22	0.5751	post session	16	0.2411
Spy hop (Point)	T stat	P value	Spy hop (Point)	T stat	P value	Spy hop (Point)	T stat	P value
pre session	5	0.4795	pre session	5	1	pre session	14	0.558
post session	12	0.7257	post session	10.5	0.1419	post session	20.5	0.8091
Regurgitation (Point)	T stat	P value	Regurgitation (Point)	T stat	P value	Regurgitation (Point)	T stat	P value
pre session	3	0.2229	pre session	1	*0.0101	pre session	0	**0.004

								8
post session	2	0.1308	post session	0	**0.006 5	post session	0	*0.0173

Note: *T* stats and *P* values are result of Wilcoxon Signed Rank Test; *p<0.05, **p <0.01

TABLE 8 Pairwise comparison of the four dolphins' activities including five state and two point events during pre-session and post-session conditions

Difference between Toto and Ginsan			Difference between Toto and Anson			Difference between Ginsan and Anson		
Swim	T stat	P value	Swim	T stat	P value	Swim	T stat	P value
pre session	8	*0.0469	pre session	14	0.1688	pre session	19	0.3863
post session	24	0.7213	post session	9	0.0593	post session	8	*0.0469
Side Swim	T stat	P value	Side Swim	T stat	P value	Side Swim	T stat	P value
pre session	24	0.7213	pre session	19	0.6784	pre session	25	0.799
post session	25	0.7989	post session	5	*0.0218	post session	3	*0.0125
Belly up swim	T stat	P value	Belly up swim	T stat	P value	Belly up swim	T stat	P value
pre session	26	0.8785	pre session	11	0.1731	pre session	12	0.2135
post session	21	0.5076	post session	27	0.9594	post session	24	0.7213
Stationary observation of the poolside	T stat	P value	Stationary observation of the poolside	T stat	P value	Stationary observation of the poolside	T stat	P value
pre session	19	0.3863	pre session	11	0.1731	pre session	14	0.1689
post session	10	0.2626	post session	20	0.7671	post session	12	0.2135
Head up swim	T stat	P value	Head up swim	T stat	P value	Head up swim	T stat	P value
pre session	15	0.2026	pre session	5	*0.0218	pre session	11	0.1731
post session	26	0.8785	post session	24	0.7213	post session	26	0.8785
Spy hop (Point)	T stat	P value	Spy hop (Point)	T stat	P value	Spy hop (Point)	T stat	P value
pre session	7	0.8918	pre session	6	0.3173	pre session	7.5	0.5176
post session	6	0.0849	post session	11.5	0.6646	post session	3	0.0537
Regurgitation (Point)	T stat	P value	Regurgitation (Point)	T stat	P value	Regurgitation (Point)	T stat	P value
pre session	3.5	*0.024	pre session	9.5	0.1219	pre session	20	0.4407
post session	0	*0.011	post session	4.5	0.102	post session	2	*0.040

Note: *T* stats and *P* values are result of Wilcoxon Signed Rank Test; *p<0.05, **p <0.01

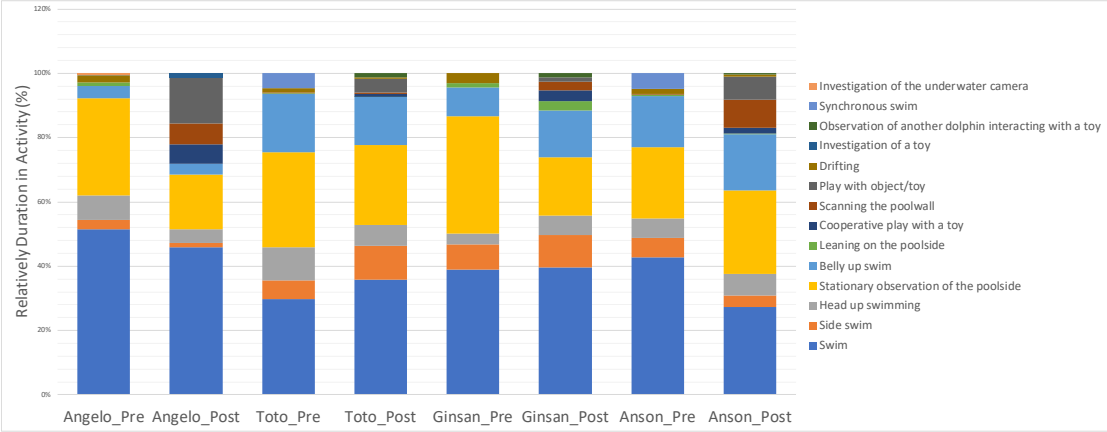

FIGURE 3 Relatively activity of each dolphin before (Pre) and after (Post) sessions.

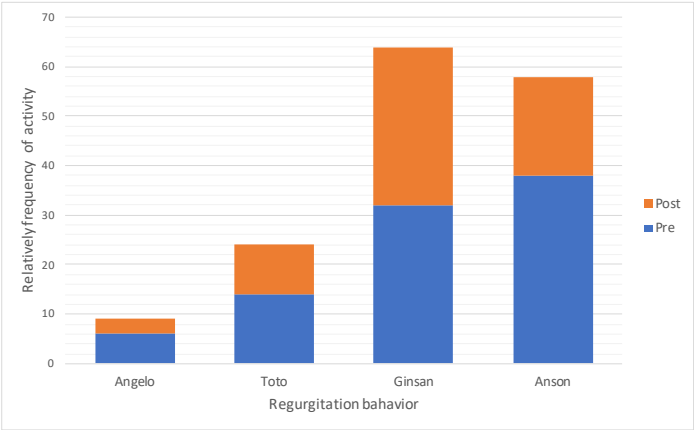

FIGURE 4 Relatively frequency in "Regurgitation " behavior of each dolphin before (Pre) and after (Post) sessions.

3.4 Pre-sessions vs Post-sessions

The comparison of each dolphin behaviors between the pre-session and post-session condition showed no significant differences (Table 9).

TABLE 9 Comparison of each dolphins' behaviors between pre- and post-session

Dolphin pairs	T stat	P value
Angelo	1.1587	0.2522
Toto	-0.5068	0.6146
Ginsan	-0.0385	0.9694
Anson	1.0969	0.2781

Note: *T* stat and *P* values are the result of a two-sided, T-test

From the five state behaviors none of them showed significant differences in dolphins between pre- and post-session conditions (Table 10). From the two point behaviors only one (Regurgitation) showed significant differences in Anson between pre- and post-session conditions (Table 10). When analyzing the four dolphins behaviors separately, the only significant difference was observed in “Regurgitation” behavior between Anson pre session (38 times) and Anson post session (20 times) (Table 10).

TABLE 10 Pairwise comparison of the four dolphins behaviors including five state and two point events between pre-session and post-session

Angelo			**Toto**		
Swim	T	P	Swim	T	P
pre-post	22	0.575	pre-post	19	0.386
Side Swim	T	P	Side Swim	T	P
pre-post	12	0.735	pre-post	12	0.114
Belly up swim	T	P	Belly up swim	T	P
pre-post	16	0.779	pre-post	22	0.575
Stationary observation of the poolside	T	P	Stationary observation of the poolside	T	P
pre-post	21	0.508	pre-post	21	0.859
Head up swim	T	P	Head up swim	T	P
pre-post	10	0.139	pre-post	15	0.203
Spy hop (Point)	T	P	Spy hop (Point)	T	P
pre-post	5	0.123	pre-post	2.5	0.357
Regurgitation (Point)	T	P	Regurgitation (Point)	T	P
pre-post	3	0.461	pre-post	11	0.608
Ginsan			**Anson**		
Swim	T	P	Swim	T	P
pre-post	25	0.798	pre-post	12	0.114
Side Swim	T	P	Side Swim	T	P
pre-post	17	0.284	pre-post	14	0.169
Belly up swim	T	P	Belly up swim	T	P

pre-post	12	0.214	pre-post	27	0.959
Stationary observation of the poolside	T	P	Stationary observation of the poolside	T	P
pre-post	7	0.066	pre-post	16	0.241
Head up swim	T	P	Head up swim	T	P value
pre-post	10	0.139	pre-post	25	0.799
Spy hop (Point)	T	P	Spy hop (Point)	T	P value
pre-post	8.5	0.666	pre-post	8	0.306
Regurgitation (Point)	T	P	Regurgitation (Point)	T	P value
pre-post	13	0.865	pre-post	3	*0.0196

Note: *T* stats and *P* values are result of Wilcoxon Signed Rank Test; *p<0.05, **p <0.01

4 Discussion

Our result suggested that in general, the cognitive research sessions had no significant impact on changing the behavioral pattern of the four dolphin subject. No difference was found between pre- and post-session conditions. Two events (drifting and scanning the poolwall) showed significant change in duration. Jensen, Delfour, and Carter (2013) found that activity levels of dolphin subjects were decreased before shows, while the vigilant behavior increased. Lopez Marulanda et al. (2016) found that after training sessions, the emission rate of whistles produced by dolphins drastically increased, as a potential indication of increased social interactions. Walker et al. (2017) also found that environmental enrichment tended to increase the social play duration. The 'spy hop' behavior was investigated and considered vigilant action in previous study (Muller et al., 1998), thus the decrease of that in post sessions could be a potential sign of robust psychological health in subjects after training sessions. These studies came to the hypothesis that the environmental enrichment sessions may help increase social bonding among dolphins. In our study, we did find that the duration and frequency of social and play behaviors were slightly higher in post-sessions than in pre-sessions. However, it was not significant; moreover, in our sessions, toys were not provided in pre-sessions while provided in post-sessions, which undermined the

validity of former result. In Trone, Kuczaj, and Solangi (2005)'s study, three dolphins participated in Dolphin interactions programs with guests, and behaviors data of pre- and post-sessions were collected. Results showed no changes in the frequencies of social events, while play being more frequent during the post-sessions, as a sign of robust psychological health. Future study, with larger data set, may produce stronger evidence. However, as no aggressive behaviors were recorded and as the behavior patterns did not indicate decline in social or play behaviors, the cognitive enrichment sessions were unlikely to be detrimental to dolphins' well-being.

In individual study of social behaviors, we found that Angelo was the most active subject accounted for nearly half of the social time duration, while Toto and Ginsan were less active in social connections. Since all subjects are male and have adopted the environment of Ocean Park, there are two possible explanation for this difference, the age or the personality of subjects. Walker et al. (2017) found no significant behavior differences in age comparisons, while this study, in which Angelo was 5 years old, Toto 27 and Ginsan 12, supports the idea that younger dolphins tends to conduct more social interactions. On the other hand, previous studies suggest that individual personality should be considered into context of analysis. In fact, the other part of this study, Matrai, Ng, Chan, Gendron, and Dudzinski (2020) have demonstrated that different individuals reacts drastically different to cognitive enrichment devices. Combined with other part of data set, the influential factors on social behaviors can be further determined.

As to frequency analysis of point events, differences between pre- and post-sessions of all three types: regurgitation, spy hop and bubble blowing were significant, among which the decrease of regurgitation frequency of subjects shown in this study could be a potential benefit of the cognitive enrichment devices. Regurgitation was formerly considered an abnormal behavior and related to boredom, illness, decease in a previous level of interaction, social instability, lack of adaption to training techniques, misinterpreting fish as a play item, etc (Messinger, 1996). Previous study found that by

introducing playing toys to two female adult bottlenose dolphins, the frequency of regurgitation was drastically decreased (Chin, Kanda, Uwano, Tomonaga, & Nakajima, 2015). When considering frequency of regurgitation alone in pre- and post-sessions of different subjects, only that of Anson decreased significantly, meaning the former impact varies among individuals. In respect of the changes in each state events between pre- and post-sessions, significant differences took place among several pairs. Also noted that the data set analyzed in this study is just a subset of a bigger data collection. An interesting trend in the result is that in post-sessions, subjects tended to spent more time in social and play behavior than in post sessions. However, since the difference is not statistically significant, whether this conclusion holds requires further investigation.

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