

Fluke-made bubble rings as toys in bottlenose dolphin calves (*Tursiops truncatus*)

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Abstract

Cetaceans display considerable patterns of bubble formation and manipulation for different purposes. While position and acoustic functions of bubbles have been extensively discussed, few details are known about their use in playing behaviour. The aim of the present work was to conduct a systematic observational study on a novel pattern of fluke-made bubble rings (FBR) and associated play behaviour in two captive calves of *Tursiops truncatus*. The birth of two, half-siblings bottlenose dolphins less than one month apart in the same aquarium presented a good opportunity to address the issue of individual differences and possible mimicry of such behaviour. Focal animal sampling (Altmann, 1974) sessions lasting 15 min were carried out for each calf according to a decreasing temporal schedule. The following parameters were scored and obtained for each calf: (a) mean frequency of FBR per session, (b) FBR by time of day, and (c) frequency of FBR associated play behaviour per session. FBR formation appeared to be, for both animals, a two-phase action producing a loud percussive sound. A trend in the mean frequency of FBR suggests a possible seasonal negative relationship with human activities. Moreover, the two calves usually were seen together and mimicked each other during FBR formation. Finally, 7 different behavioural categories were observed after FBR formation and their sequence appeared to be well defined.

In conclusion, this paper describes a novel form of play in two bottlenose dolphin calves. Even though data are limited by a small sample size and are only suggestive, they do indicate that FBR formation and the calves' ability to manipulate bubble rings could reflect the learning flexibility of the young dolphins and implies a high behavioural versatility.

Key words: play behaviour, bubbles, bottlenose dolphin, *Tursiops truncatus*, toys, imitation, calves.

Introduction

Play is an important component of the developmental sequence in many mammals and birds (Fagen, 1981) and often is defined as activity not directed towards the satisfaction of a utilitarian need. Investigators attribute a wide range of functions to play behaviour (Fagen, 1981; Bekoff, 1984; Martin & Caro, 1985), including aiding the process of growth and development, learning about the environment, practising adult activities, and establishing social relationships (Bekoff, 1988; 1992). All have in common that, as a result of playing when young, the individual is better able to perform some form of useful behaviour later in life.

By reviewing the available literature, it was quite clear that many terrestrial mammals limit play to a short period of their youth. On the other hand, aquatic mammals such as cetaceans seem to exhibit play during their whole life (Gewalt, 1989; Bel'kovich *et al.*, 1991). Norris & Dhol (1980) reported that in some cetacean species play seems inextricably linked to cultural learning, and its functions are to be found, at least in part, in the establishment of finely tuned behaviours such as leaping, bow-riding, and various social interactions. Play is a prominent part of wild dolphin school behaviour, perhaps only fully expressed in the safety of the school. It is common to observe both young and adult dolphins repeatedly practising aerial patterns such as spins, leaps, breaches, and fin- and head-slaps, as well as surf-riding waves in out, and other kinds of water-supported play. Moreover, manipulating, carrying, and trading objects, such as different species of fish and jellyfish, by throwing them repeatedly into the air, and similar observations, occur both in nature (Norris & Prestcott, 1961; dos Santos & Lacerda, 1987; Bel'kovich *et al.*, 1991; Norris *et al.*, 1994) and in captivity (Caldwell & Caldwell, 1972; Defran & Pryor, 1980; Gewalt, 1989; Denking & von Fersen, 1996).

Dolphins must have some exquisite control that of their bodies in the three-dimensional weightless

world in which they live. In this respect, some descriptions of captive play in young dolphins include remarkable examples of inventiveness (McBride & Hebb, 1948; Tavalga, 1966). Researchers noted that cetaceans display several patterns of bubble formation and manipulation for different purposes (Jurasz & Jurasz, 1978; Gewalt, 1989; Pryor, 1990; Norris *et al.*, 1994; Dudzinski, 1996; Fertl & Wilson, 1997). While position and acoustic functions of bubbles were well discussed (see Norris *et al.*, 1994 for a review in *Stenella longirostris*), few details were provided for their use in play behaviour. A specifically remarkable type of bubble formation, play, and manipulation was described by Gewalt (1989) in captive *Inia goeffrensis*. The same author also reported that belugas (*Delphinapterus leucas*) use air bubble as toys in the Aquaria of Vancouver and New York.

A review of bubble formation in *Tursiops truncatus* in captivity was detailed by Marten *et al.* (1996). As for rings made from blowhole air and from surface air, the authors described that the animals generated different kinds to play with, using various techniques to form them.

The aim of the present work was to conduct a systematic observational study of the development of a novel particular pattern of fluke-made bubble ring formation (FBR), and associated play behaviour in two captive calves of *Tursiops truncatus*. The birth of two, half-sibling bottlenose dolphins less than one month apart in the same aquarium presented a good opportunity to address individual differences and possible imitation of FBR behaviour.

Materials and Methods

Animals and environment

Subjects of the study were two newborn male bottlenose dolphins (*Tursiops truncatus*) housed in the Aquatic World Dolphinarium in Cattolica, Italy. 'Tabo' and 'Golia' were born in the same pool on 15 June 1993, and 6 July 1993, respectively.

The open-air oval pool (19 × 15 m; capacity of 100 m³; surface of 300 m²; maximum height of 3.6 m) was equipped with six underwater windows (80 × 70 cm).

Hygienic conditions were controlled by means of a close-circuit water system, and the pools' conic bottom promoted concentration of the animals' waste matter. The water was checked weekly for the presence of bacteria and kept under 20 colonies/100 ml. A chemical conditioning system controlled the intake of sodium hypochlorite-based disinfectants kept in the range of 0.4–0.7 ppm, pH was between 7.7 and 7.9, and the water density was approximately 25–33 g/l. Water temperature

oscillated, according to the season, between 13 and 27°C.

Data collection and analysis

Mothers and calves were monitored from birth to 106 weeks of age to set up a specific ethogram for the mother-calf relationships in these captive conditions.

Focal animal sampling (Altmann, 1974) sessions lasting 15 min were carried out for each mother-calf pair according to a decreasing temporal schedule. Observation times were randomized among 2-hr periods and balanced for equal representation within a week and at different times of day. However, a portion of the night (from 02:00 to 06:00 am) was excluded, because mothers and calves spent resting most of their time.

Because fluke-made bubble ring (FBR) behaviour had a defined start and end date, data only from weeks 44–94 for Tabo and weeks 41–91 for Golia were analysed. The observation schedule for that interval was 10 focal animal sessions per 3 weeks.

Using a cassette recorder, chronometer and a check-list, the following measurements were collected and scored for each calf:

- (a) mean frequency of FBR per session;
- (b) FBR by time of day;
- (c) frequency of FBR associated play behaviours per session (see Table 1).

Mean frequencies of FBR per session were analysed by mixed-model factorial ANOVA, with dolphins (Tabo vs Golia) as the 'between subject' factor, and age (repeated measures, in 3 week intervals) as the 'within subject' factor. This method also was used to compare time of day data within the 10 periods.

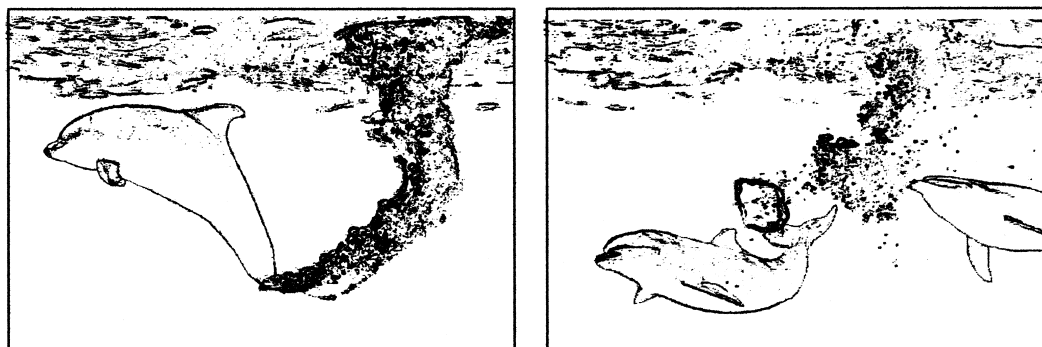
Analysis of FBR associations with play behaviour categories was performed by means of a contingency table and Chi-square test, to verify whether the association was random.

Results

Both calves produced regular air bubble rings by a previously undescribed fluke-slapping technique (FBR). FBR formation appeared to be, for both the animals, a two-phase action (Fig. 1) producing a loud percussive sound. An energetic fluke-slap against the water surface associated with a concave body arch generated a bubble curtain on the top of the fluke; then the dolphins accomplished a fluke up movement in the water associated with a convex body arch. Such a sequence generated a strong and well-defined floating ring of air bubbles of about 60 cm in dia. FBR formation required approximately 5 sec.

Table 1. Behaviours associated with fluke bubble rings.

Behaviour	Code	Description
Ring Interest/Follow	RI	Dolphin shows interest in bubble ring movements and follows it to the water surface without touching it
Ring Push	RP	Dolphin gently pushes the ring without disrupting it
Ring Bite	RB	Dolphin bites the ring to break it
Ring Through	RT	Dolphin passes through the ring to break it
Bubble Interest/Follow	BI	Dolphin shows interest for the bubbles derived from the ring rupture and/or follows them to the water surface
Bubble Bite	BB	Dolphin bites the bubbles derived from the ring rupture
Bubble Through	BT	Dolphin passes through the bubbles derived from the ring rupture

**Figure 1.** Fluke-made bubble ring (FBR) formation.

A total of 86 FBR for Tabo and 89 for Golia was recorded throughout the study. FBR were first seen from Tabo on April 1994, at week 44 of age and at week 41 for Golia. The last FBR observation was on March 1995 for both dolphins.

Age-relatedness of FBR formation was confirmed by two-way ANOVAs. The mean frequency of FBR per session showed some changes ($F_{16,144}=4.54$, $P<0.0001$) during the study (Fig. 2). This measure decreased from April to August 1994 (age 56–58 for Tabo and 53–55 for Golia), markedly increased in frequency over the following four 3-week intervals (from August to October 1994), peaking in September, and decreasing until ages of 83–85 for Tabo and 80–82 for Golia. Thereafter, FBR frequency raised again to a higher level, and reached similar lower values in the last two 3-week intervals.

A different distribution of FBR frequency (Fig. 3) appeared during the 10 daily periods ($F_{9,144}=3.77$, $P<0.005$). In fact, higher FBR mean frequencies were observed from 8:01 am to 02:00 pm, while lower ones were seen from 8:01 pm to 02:00 am, and 06:01–08:00 am. This evident diurnal pattern also was statistically significant for all the 3-week intervals ($F_{16,144}=2.59$, $P<0.0001$).

As for the individual development, the mean frequency of FBR for the two calves was virtually indistinguishable statistically on every measure. In this respect, the dolphins were usually observed together and mimicked each other during FBR formation, with a frequency of 39 (45.3%) and 48 (53.9%) instances for Tabo and Golia, respectively.

A total of 7 different behaviours were observed after FBR formation (Table 1). Ring Interest/follow (RI) and Ring Push (RP) were displayed when the ring of bubbles was intact and floating in the water. Two different ways of ring breaking were seen, Ring Bite (RB) and Ring Through (RT). Finally, three behaviours were observed relative to the different size of ruptured bubbles, Bubble Interest/follow (BI), Bubble Bite (BB) and Bubble Through (BT). Again, Tabo and Golia showed a similar pattern in the general frequency of FBR following behaviours and no statistical differences were seen.

Figure 4 shows the flux diagrams (sequential analysis) of the statistically significant frequencies (Chi-square, $P<0.05$) of the 7 behaviours occurred after FBR formation for both calves. Few differences between the two animals were found. In fact, while Golia revealed a sequence in which RT followed RI, Tabo displayed RT immediately after

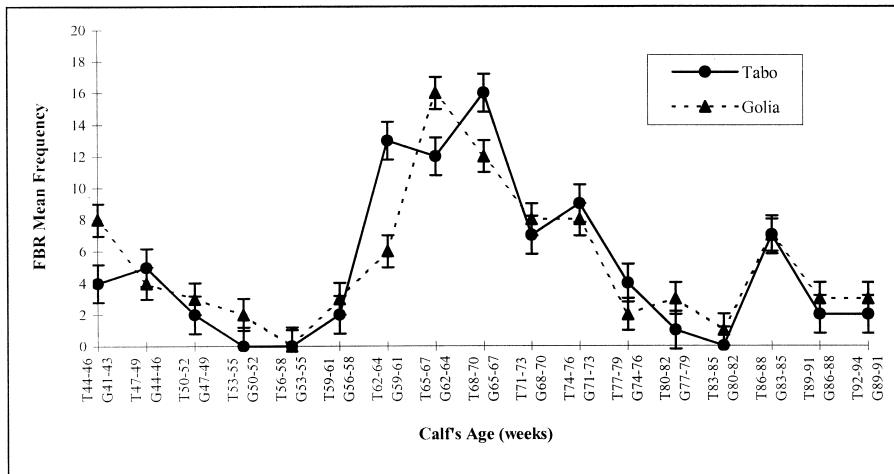


Figure 2. Mean frequency distribution of FBR during the study.

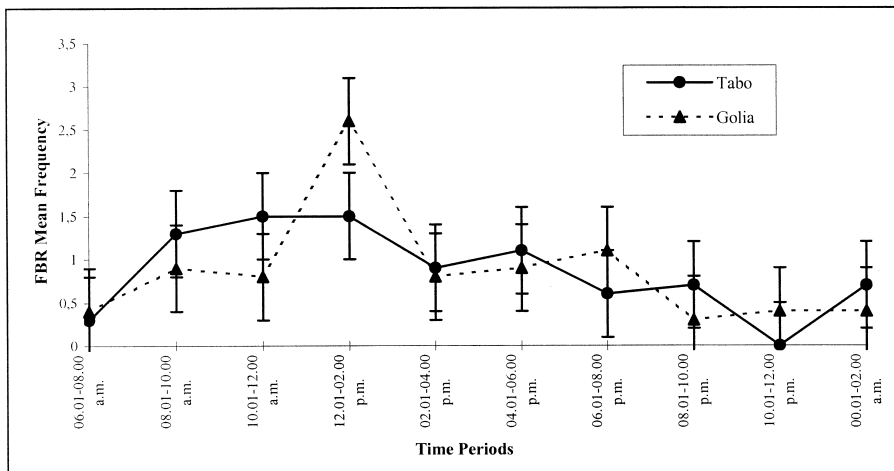


Figure 3. Mean frequency distribution of FBR during 10 daily periods.

FBR. Moreover, RB appeared to be sequential to RI for the older calf whereas the younger one did not show such a link.

On several occasions, the FBR formation was preceded or followed by other kinds of bubble formation and manipulation. In particular, both dolphins made different kinds and sizes of bubbles from their blow-hole, including long chains of little bubbles associated or not with whistles, big round bubbles, and big ring bubbles. These particular patterns happened with a total frequency of 54.8% for Tabo and 67.5% for Golia.

Discussion

The production of air-bubble rings was made by fluke slapping in two bottlenose dolphin calves

(FBR). The mean frequency of FBR formation clustered into three periods: early, from April to August 1994, later longer cycle ending in January 1995, and the last period ending in March 1995. This trend in FBR formation suggests a possible seasonal relationship and negative influence from human activities, as reported for other species (Rasa, 1971; Fagen, 1981). In fact, FBR behaviour started on April 1994, a spring period in which both training and show activities were low; then the mean frequency of this parameter reached a very low level during full summer time (middle June to middle August), when both human operations were particularly high. The next peak was during an autumnal period of a calm training and shows. The following decline of FBR formation level in December and January could have been influenced

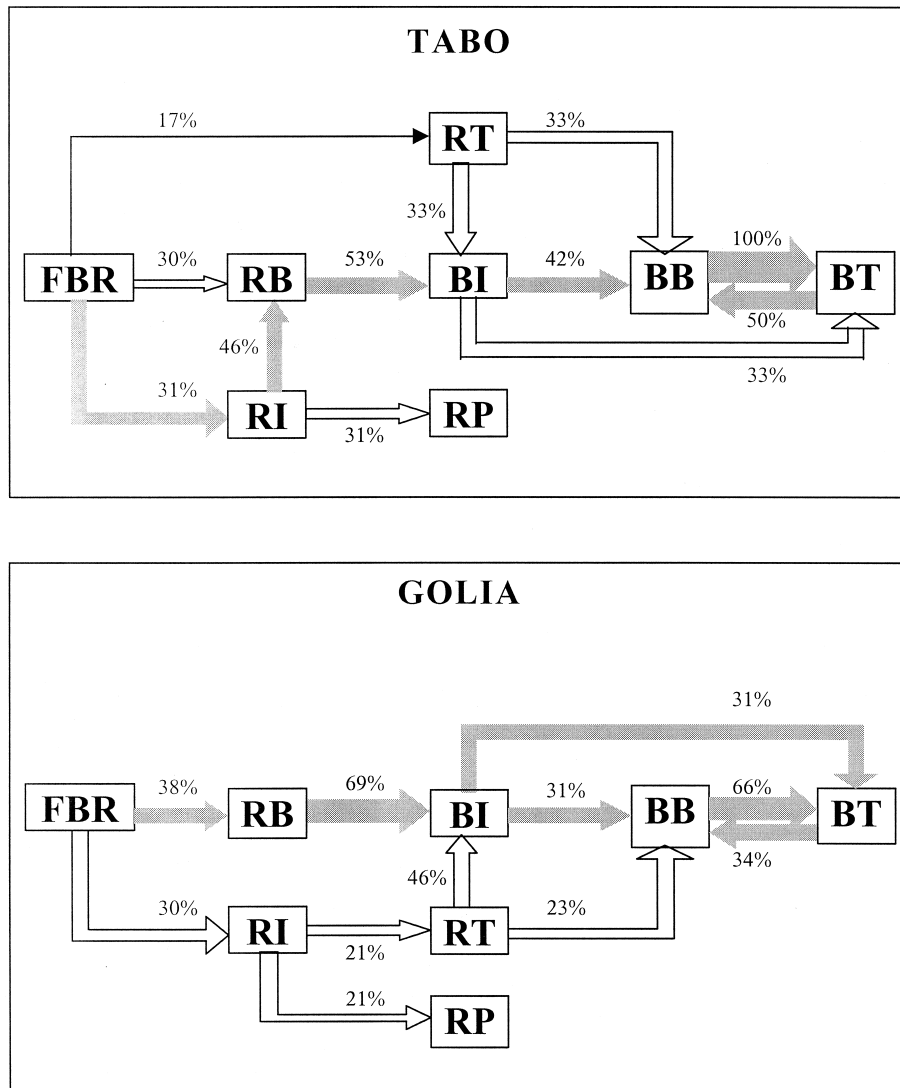


Figure 4. Flux diagrams (sequential analysis) of the statistically significant frequencies of the 7 FBR associated behaviours. The main direction is marked.

by bad weather. Finally, FBR formation again increased at the beginning of spring (February–March 1995).

According to Defran & Pryor (1980), when captive adult and young bottlenose dolphins are given free opportunity to interact with objects in their tank they generally spend a considerable amount of time manipulating them with fins or carrying on their rostrum. Complex forms of object play, involving the combination of many behavioural elements, probably requires the assumption of an independent motivational system. Pellis (1991)

noted that the idea that play involves a motivation separate from other behavioural systems is reinforced by the frequently reported observation that play only occurs when primary needs have been satisfied, and not in stressful situations. As a consequence, it could be argued that behavioural observations, such as those described above, could be explained by as the two calves making FBR as toys in the absence of other objects to play with.

Moreover, the other important characteristic of FBR formation by the calves is its spontaneity. This inventive behaviour reinforces the notion of a

broad capability for rich and innovative actions in dolphins. Tabo and Golia developed this self-governing, definite and characteristic play pattern at 9–10 months after birth and exhibited it during a precise period of their development. The related important issue is the dependence of play on more general features of sensory and motor development. Clearly, the specific nature of play observed at any stage in ontogeny is to some extent dependent on the changing capabilities of the organism (Martin & Bateson, 1985). However, the extent to which general features of sensory and motor development shape specific aspects of play remains uncertain (Bekoff & Byers, 1981). On the other hand, FBR formation seems to offer a useful method for assessing sensory-motor skill and development under conditions where the subjects' actions were entirely self-motivated.

The evident daily pattern and the high frequency of FBR formation and manipulation observed during 8:01 am to 02:00 pm periods, suggested a clear link with the visual perception system. Possibly, the major specialization of the cetacean visual system is in the processing of movement information (Madsen & Herman, 1980). Some physiological data (Dawson, 1980) involving retina's giant cells also support the hypothesis of good movement acuity in these animals, even if real movement can be hard to detect in the open ocean where there are few stable visual referents as background for moving objects.

However, changes in illumination on the moving surfaces of swimming prey animals, for example, are demonstrated to be an excellent motion stimuli (Madsen & Herman, 1980). Floating movements of FBR and after rupture bubbles, and sunlight reflections during daytime seemed to be an appropriate motion-visual stimuli for the two young.

FBR associated behavioural sequences appeared to be well defined for both calves. They displayed two precise interaction phases with the bubble rings. An observational period (RI) was followed by three different contact behaviours (RP, RB and RT) with two different functions: the first one (RP) involved gentle pushing behaviour whose aim was to change the ring shape without rupture and the other two (RB and RT) were intentional movements to cause the ring rupture and the bubbles release. Then, a second interaction phase involving BI, BB and BT was observed. These repeated playful performances implying sensory-motor acts that appeared to a human observer to be without immediate benefit, and resembled similar patterns from other contexts. The various calves' FBR following behaviours could develop into adult food procuring patterns. As Martin & Caro (1985) pointed out, structural similarity between object play and the adult predatory patterns does consti-

tute a reason for hypothesizing that the two are functionally related but is not in itself a sufficient reason for hypothesizing that the two are functionally related but is not in itself a sufficient reason for assuming this relationship. Furthermore, oceanaria, where dolphins are fed dead fish, are not a natural scenario, and should not be interpreted as such.

On several occasions (54.8% and 67.5% for Tabo and Golia, respectively), the FBR formation was preceded or followed by other kinds of bubble formation and manipulation. Both animals made different kinds and sizes of bubbles from their blowhole in a precise sequence. Tabo and Golia formed bubble chains from the blowholes during the first week of age as a result of whistling. After a few weeks, they learned to make bubble chains without whistles and interacted with these 'bubble objects'. Then, sphere or rings of bubbles also were produced from the calves' blowhole, sometimes involving their subsequent manipulation as toys. Finally, the two dolphins developed their own and specific way of bubble ring formation not reported before in other cetacean species. As a broad generalization, it seems that Tabo and Golia developed specific skills while trying out progressively more difficult bubble patterns.

Other important results of this study are the absence of differences in FBR behaviour between the two calves and the evident imitation of bubbling. The ontogenetic origins of behavioural differences, between individuals, and their functional significance (if any), are largely unknown. Moreover, true imitation, in which an animal mimics a new behaviour, may be distinguished from a common behaviour by its occurrence in another animals (Andrew, 1962). In this respect, Tabo and Golia showed a true mimicry in FBR formation because they 'invented' a novel play pattern never described before and imitated each other in its display. Among dolphins, comparable imitative tendencies are commonly seen in their games, or in their attraction toward an object being manipulated by another dolphin (Herman, 1980). These behaviours could have an adaptive basis within the closely integrated and often cooperative society that characterizes many delphinid species. Imitation could in many cases be a strong affiliative signal for dolphins (Herman, 1980).

In conclusion, this paper described the development of a novel form of object play in two captive bottlenose dolphin calves. The study was limited by the small sample size, but seems to reflect the learning flexibility of the young dolphins. Even though data are only suggestive, they do indicate that FBR formation and the calves' ability to manipulate objects (bubble rings) implies a high behavioural versatility.

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