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Underwater Mirror Exposure to Free-Ranging Naïve Atlantic Spotted Dolphins (*Stenella frontalis*) in the Bahamas

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The "mirror state," described for human self-recognition, has been found in captive or human-raised species. In marine mammals, bottlenose dolphins and killer whales have shown evidence of body examination, self-directed and contingency checking behaviors whereas false killer whales appeared ambiguous and California sea lions did not recognize themselves in a mirror. Self-recognition processes in wild cetaceans remain unknown. Since 1985, a resident community of Atlantic spotted dolphin (*Stenella frontalis*) has been studied underwater in the Bahamas. We describe the reaction of free-ranging dolphins during 14 exposures to the presence of a mirror from 1994/1995 and 2004/2005. Responses to the mirror were mixed. Initial reactions of mother/calf groups were to swim around mirror and stay in close physical proximity. Others ignored the mirror entirely, or swam around or underneath. A single male became stationary and postured in an aggressive stance in front of the mirror. The wild spotted dolphins showed a significant preference to exposing and/or orienting their right side to the mirror *versus* their left side. We suggest that the animals assign different meanings to a mirror in the wild versus the same object in captivity.

Recognition of its mirror image, or self-recognition, with the use of the mark test has been demonstrated in humans (Fontaine, 1992; Lacan, 1949; Wallon, 1945; Zazzo, 1969), in anthropoid apes, like chimpanzees (*Pan troglodytes*), bonobos (*Pan paniscus*), orangutans (*Pongo pygmaeus*) and more controversially gorillas (*Gorilla gorilla*), in one species of birds (i.e., magpies, *Pica pica*), in a terrestrial mammal (i.e., elephants, *Elephas maximus*), and more debatably in cetaceans, including bottlenose dolphins (*Tursiops truncatus*) and killer whales (*Orcinus orca*) (Delfour & Marten, 2001; Gallup, 1970; Gallup, Anderson, & Shillito, 2002; Hyatt & Hopkins, 1994; Marino, Reiss, & Gallup, 1994; Marten & Psarakos, 1994; Plotnik, de Waal, Moore, & Reiss, 2009; Prior, Schwarz, & Güntürkün, 2008; Reiss & Marino, 2001; Suarez & Gallup, 1981). In dolphinariums, bottlenose dolphins and killer whales have shown evidence of body examination, self-directed and contingency checking behaviours when confronted to their specular image. The results for false killer whales (*Pseudorca crassidens*) and sea lions (*Zalophus californianus*) indicated that they did not display self recognizing behaviours (Delfour, 2006; Delfour & Marten, 2001).

The interpretation of exposure to mirrors by free-ranging, non-marked, animals, whose Umwelts (i.e., "subjective universes") differ (von Uexküll, 1956) may require a broader theoretical base and new paradigms. We suggest constructivist ethology to interpret the subject's behaviours. Through action and sense, each animal ascribes meaning to its environment. No objective world exists, rather multiple context-dependent cognitive and subjective world emerge (Delfour, 2010).

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In the Bahamas, the surface and underwater behaviour of a resident group of Atlantic spotted dolphins (*Stenella frontalis*) has been documented since 1985. This species is closely related to bottlenose dolphins that have, after humans, the second largest encephalization quotient and also complex cognition (Marino, 2002; Marino et al., 2007). The life history of individual dolphins in this community has been well documented and individuals are easily recognized on site in the wild (Herzing, 1996, 1997, 2000, 2006). Some field studies of dolphins in the wild have attempted to infer cognitive abilities from observations of behavior and social interactions (Bender, Herzing, & Bjorklund, 2008; Connor & Krutzen, 2003; Connor & Mann, 2006).

The present pilot study was designed to expose a group of semi-habituated free ranging dolphins to a mirror and analyze their first reactions as naïve subjects. It is unlikely that these free-ranging dolphins have been exposed to a mirror, although past exposure to conspecific reflections under the surface and reflected images from underwater video ports is possible. We wanted to assess their capacity to recognize themselves based upon their own mirror reflection. We also analyzed the spotted dolphins' body orientation in the vicinity of the mirror, since previous studies have reported a left hemispheric bias in bottlenose dolphins (*Tursiops truncatus*) while being exposed to non-social, social, and/or unfamiliar stimuli (Blois-Heulin, Crével, Böye, & Lemasson, 2012; Delfour & Marten, 2006; Morrel-Samuels & Herman, 1993; von Fersen, Schall, & Güntürkün, 2000; Yaman, von Fersen, Dehnhardt, & Güntürkün, 2003). Given the free-ranging nature of the dolphins and the lack of a "mark test" and experimental control, although interesting should be viewed with caution according to the limitations of the study.

Method

Since 1985, over 220 individual Atlantic spotted dolphins (*Stenella frontalis*) have been identified using photographs and video of dorsal fins, flukes and constellations of spots and their matrilineal lines confirmed by DNA analysis (Green, Herzing, & Baldwin, 2011; Herzing, 1997). On-going monitoring of this community of dolphins in an approximately 480 km^2 area continues with the majority of individuals and their relationships well documented.

Dolphins of various age classes and sexes, and in during different behavioral contexts, were exposed to a mirror in the water (Plexiglas 3' x 3' covered with reflective material), 6 times in 1994, 5 times in 1995, once in 2004 and twice in 2005 (Table 1). Researchers regularly entered the water to record the social and non-social behaviour in this community of dolphins but for mirror exposures the following occurred: Swimmer A entered the water and vertically presented a mirror while Swimmer B recorded underwater reactions of the exposed dolphin group using a Sony PC110 video camera with hydrophone input. Focal sampling and continuous recording documented the dolphins' reactions to the swimmer holding the mirror and/or the mirror itself (Altmann, 1974). A behavioural repertoire was specifically designed for this study including behavioural items displayed in the vicinity (<1 dolphin length) of the mirror (Table 2).

Table 1
Mirror exposures with behavioral contexts, duration and social grouping of exposed dolphins

Exposure	Date	Behavioural context of mirror presentation	Duration of mirror presentation (sec)	Social grouping of dolphins present during the exposure (sex and age class)*
1	07/11/94	fishing/play	84	7 ♀ (f, 4m, 1s, 2t) and 1 ♂ (t)
2	07/12/94	travel/play	46	7 ♀ (3m, 2s, 2t), 2 unsexed (m, t)
3	07/12/94	travel/play	158	1 ♀ (m)
4	07/12/94	travel/play	68	5 ♀ (f, 4m) and 8 ♂ (3f, m, 3s, 2t)
5	07/12/94	aggression	100	1 ♂ (m)
6	07/23/94	Play	116	1 ♀ (m)
7	06/10/95	Play	134	4 ♀ (2m, 2t)
8	06/10/95	Play	47	2 unsexed (m, t)
9	06/10/95	Play	52	1 ♀ (m)
10	06/10/95	Play	71	2 unsexed (m, t)
11	06/10/95	Play	56	1 ♀ (m)
12	07/25/04	court behaviour	160	5 ♀ (3f, 2m), 6 ♂ (f) and 1 unsexed (m)
13	08/11/05	Play	416	2 ♀ (f, s)
14	08/12/05	Play	292	4 ♀ (f, 2s, t) and 5 ♂ (2f, 3s)

* with ♀: female and ♂: male, and dolphins'age classes f: fused - old adult, m: mottled - young adult, s: speckled – juvenile and t: two-tone – calf.

Table 2
Behavioural repertoire

Behaviour	Description
To orient	The dolphin positions one side and/or its head parallel to mirror
To swim by	The dolphin keeps swimming while approaching the mirror and doesn't stop
To circle around	The dolphin swims around the mirror making circles
To approach	The dolphin swims towards the apparatus
To face	The dolphin positions its head towards the mirror (facing)
To orient/body mvt	The dolphin positions one side and/or its head parallel to mirror, the dolphins repeatedly moves its body
To look at	The dolphin orients its head parallel to mirror and uses its monocular vision, most of the time the dolphin will make a brief stop
To swim underneath	The dolphin dives and swims underneath the apparatus (in upright or upside down position)

Results

Wild spotted dolphins were exposed to a mirror from 1994 to 2005 in the Bahamas. We analyzed 14 exposures lasting from 46 to 416 s (M = 128.57, SD = 105.89). The exposures greatly varied in time, showing that the dolphins spent various durations in the vicinity of the mirror (KW = 51.28, $p < 0.0001$). Moreover, females seemed to be more interested than males: we examined the behaviours of 37 females *versus* 21 males and 5 unsexed dolphins.

Dolphins' Behaviours While Approaching the Swimmer Holding the Mirror

In presence of the mirror, the spotted dolphins displayed significant differences in swimming by mirror, circling around mirror and in orienting towards mirror (KW = 40.86, $p < 0.0001$) (Figure 1). The total durations of dolphins' circling around the mirror was greater than the time spent in swimming by (Dunn's Multiple Comparison Test = -40.73, $p < 0.001$) or in orienting towards the mirror (Dunn's Multiple Comparison Test = 53.77, $p < 0.001$).

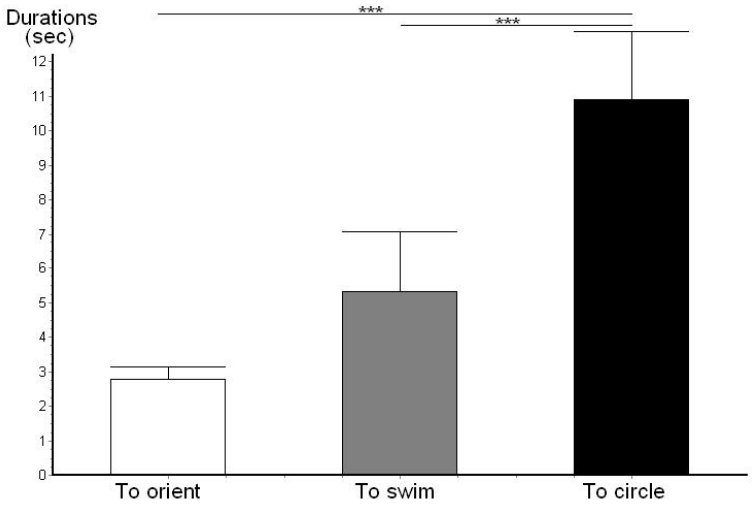

Figure 1. Total durations (sec) of the following behaviours: to orient towards mirror, to swim by mirror and to circle around mirror (*** means $p < 0.001$). Vertical bars depict SEM.

Behaviours Displayed in the Close Vicinity of the Mirror

The spotted dolphins showed a significant difference in the durations of looking and swimming underneath the mirror (KW = 20.26, $p < 0.001$) (Figure 2). They spent more time displaying these behaviours than displaying approach behavior (respectively Dunn's Multiple Comparison test: -32.20, $p < 0.05$; and -43.65, $p < 0.01$).

Lateralization in Exposition/Orientation

The spotted dolphins showed a significant difference in their visual and/or body lateralization (KW = 7.69, $p < 0.05$) (Figure 3) and tended to expose their right side longer than their left side to the mirror (Dunn's Multiple Comparison Test: -19.72, $p < 0.05$).

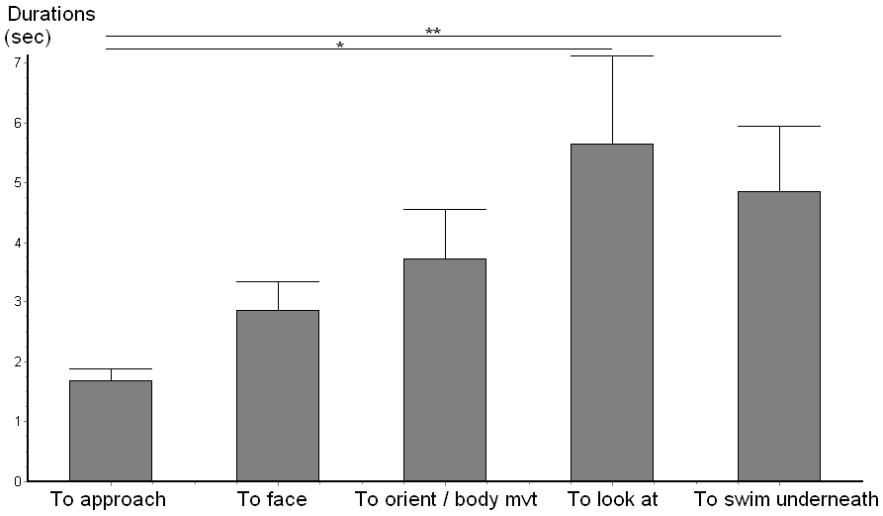

Figure 2. Total duration (sec) of behavioural bouts displayed close to the mirror (* $p < 0.05$ and ** $p < 0.01$).

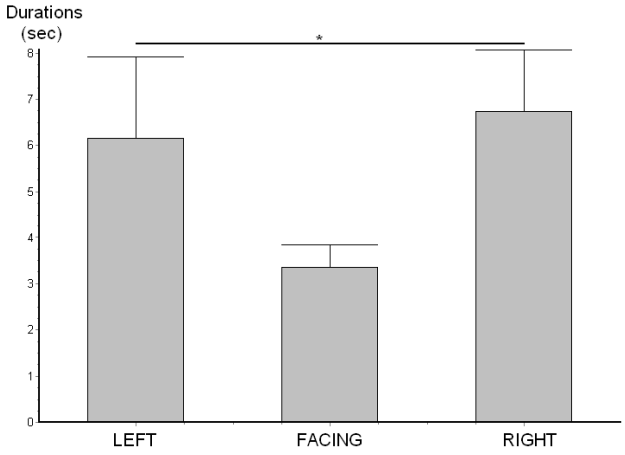

Figure 3. Total durations (sec) of left side exposure behaviour, right side exposure behaviour and facing behaviour (* means $p < 0.05$). Vertical bars depict SEM, with left side exposition: mean = 6.15, SEM = 1.78; facing behaviour: mean = 3.34 and SEM = 0.50, and right side exposition: mean = 6.74 and SEM = 1.34.

Discussion

The Behavioral Interpretation

Contrary to previous studies conducted with mark tests on captive bottlenose dolphins (*Tursiops truncatus*) (Marino et al., 1994; Marten & Psarakos, 1994) or killer whales (*Orcinus orca*) (Delfour & Marten, 2001), the mirror did not elicit contingency-checking in wild Atlantic spotted dolphins (*Stenella frontalis*). Dolphins preferred to circle around the mirror rather than to swim by or to orient towards the mirror. Their behaviour is a likely attempt to explore behind an object that they are unable to penetrate with their echolocation (Delfour & Marten, 2001). When

analyzing the dolphins' behaviours in the vicinity of the mirror, they looked at the apparatus (and the swimmers), they swam underneath it, then in a less proportion they oriented toward the mirror, moved their body in front of the mirror or positioned themselves in front of it. Although there were less typical "contingency checking" behaviours (e.g., body movements while looking at the mirror) than we would predict from past mirror studies with other dolphin species we should keep in mind that these free-ranging dolphins were not "marked" as in other mark tests. It is worth noting that in one case a single male dolphin (of maturating age) became stationary and postured in an aggressive stance in front of the mirror and then rapidly moved away. This particular mirror exposure occurred during a natural aggressive encounter between other male dolphins in the group. Was it a display of agonistic behaviour? If so, then the natural behavioural context of aggression may have influenced the reaction to the mirror by the male dolphin exposed, suggesting the important necessity to understand any behavioural context while trying to interpret the animal's behaviour.

The Cognitive Interpretation

We explored the dolphins' laterality while approaching and/or looking at the mirror. The wild spotted dolphins showed a significant preference to exposing and/or orienting their right side to the mirror *versus* their left side, suggesting that they were primarily using their left hemisphere (contralateral with side). Previous studies have reported a similar hemispheric bias in bottlenose dolphins (*Tursiops truncatus*) while being exposed to non-social, social, and/or unfamiliar stimuli (Blois-Heulin et al., 2012; Delfour & Marten, 2006; Morrel-Samuels & Herman, 1993; von Fersen et al., 2000; Yaman et al., 2003). Dolphins also received higher scores while testing cross-modal associations stimuli (i.e., visual and auditive) (Delfour & Marten, 2006) when using their left hemisphere. A preferential use of the right eye (left hemisphere) during visual inspection of unfamiliar targets has also been reported in wild striped dolphins (*Stenella coeruleoalba*) (Siniscalchi, Dimatteo, Pepe, Sasso, & Quaranta, 2012). Opposite findings, left-eye preference, was found in socializing wild mother-calf white whales dyads (*Delphinapterus leucas*), indicating that analysis of socially significant visual information occurs in the right brain hemisphere (Karenina, Giljov, Baranov, Osipova, & Krasnova, 2010). Even if the right eye (left hemisphere) seems to be used to treat unfamiliar or non-social stimuli, the right hemisphere seems to be involved in the treatment of information on social partners and novel objects. Here wild spotted dolphins seemed to slightly prefer to use their right side / left hemisphere, however it is impossible to conclude if they treated the stimulus "human holding a mirror" as simple or complex or if they considered the stimuli as a social partner or a novel object. It would be interesting in the future to present the mirror without a human holding it.

In our mirror exposure study, wild dolphins did not direct much attention to the mirror or do any specific contingency checking and body exploration as seen in captive studies. The tendency for interpretation is usually to view the animals' worlds through a cognitivist perspective (Marino & Frohoff, 2011). However, to explain the lack of self-exploratory behaviors displayed by these wild spotted dolphins, we believe it would be beneficial to carefully think about their Umwelts. We do not think the conclusion of this experiment should be: "wild spotted dolphins didn't recognise their mirror image, i.e., they are not able of self-recognition." Instead, scientists should rethink the paradigms they want to test on wild animals and the conceptual backgrounds and theories used to analyse and interpret animals' behaviours (Delfour, 2010). The transposition of such experiments, conducted on captive animals to their wild counterparts,

suggests that we need other frameworks besides reductionistic. It might be more appropriate to interpret their reactions by first understanding who the dolphins are in their own world and what dolphin-specific meanings are ascribed to various aspects of their surroundings, both natural and artificial, within their own societies.

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