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Patterns of Interactive System Use by Bottlenose Dolphins (*Tursiops truncatus*)

by

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Abstract

In the 1970s through the 1990s, artificial languages and codes were being used as a window into understanding different species' cognitive abilities and to afford them choice and control in captive environments. In a study by Reiss and McCowan (1993), two young captive born male bottlenose dolphins (*Tursiops truncatus*) and their mothers were given an underwater interactive system that afforded them some degree of choice and control in obtaining specific contingencies. The dolphins' use of specific visual elements presented via on a 3 x 3 key matrix resulted in the production of computer generated whistles followed by the delivery of objects and activities. The analysis of the original study focused on vocal learning, spontaneous vocal mimicry and productive use of novel sounds by the two young dolphins. The dolphins' use of the keyboard and concurrent behavior was examined and described in relationship to their acoustic behavior but not quantified further. The goal of the current study was to revisit the data from Reiss and McCowan (1993) and to quantify and describe the dolphins' keyboard use and behavior during experimental sessions, as well as other aspects of learning. The two young dolphins showed a change in keyboard use over time, with both ultimately tracking preferred keys. Keyboard use and the dolphins' behavior reveal a correspondence with the acoustic findings of the original publication. Overall, the results suggest the co-development of the dolphins' acoustic learning, keyboard usage, and overall behavior.

Keywords: interactive system, bottlenose dolphin, Tursiops truncatus, choice and control, keyboard, learning, behavior, spontaneous symbol acquisition

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Patterns of Interactive System Use by Bottlenose Dolphins (*Tursiops truncatus*)

In the 1970s through the 1990s, researchers became interested in using artificial languages and codes as a window into understanding the cognitive abilities of different species. While much of the work focused on great apes and psittacines, dolphins represented another taxa with comparable capabilities, which rendered them ideal research candidates for this approach. Reiss and McCowan (1993) conducted the first study that employed an artificial code integrated into an interactive system for dolphins: an underwater keyboard apparatus that, when utilized, granted them more choice and control in their environment. The goal of their research was two-fold: 1) to investigate the dolphins' cognitive and vocal learning abilities and 2) to document how dolphins would interact with a system that provided them with degrees of choice and control. Prior to this study, dolphins were considered to be one of the few species to show vocal learning, beyond humans and avian species (Bloom, Hood, & Lightbown, 1974; Kroodsma & Pickert, 1984). Specifically bottlenose dolphins had shown a proclivity for vocal imitation and for the spontaneous imitation of species-specific whistles (Tyack, 1986). However, little was known regarding the process of vocal learning in this species.

In order to explore this topic in more detail, a social group of captive bottlenose dolphins (*Tursiops truncatus*), two mother-calf pairs, were presented with an interactive underwater keyboard (Reiss & McCowan, 1993). When a visual form displayed on a key within a 3 x 3 key matrix was pressed by a dolphin, a specific and novel computer-generated whistle was played into the dolphin pool, followed by the delivery of the corresponding object or activity. None of the four dolphins had received any explicit training using the keyboard and they were not reinforced by the experimenters for imitating the computer-generated whistles. The two calves, not their mothers, interacted with the keyboard. They not only exhibited spontaneous vocal learning and mimicry but they also imitated the specific acoustic parameters of the computer-generated whistles with great fidelity and more rapidly than dolphins that had received explicit training in other studies of vocal learning (Richards, Wolz, & Herman, 1984). These findings suggested that the dolphins had made associations between the visual symbols, the acoustic signals, and the objects and activities that were temporally linked during keyboard interactions. However, the dolphins' use of specific keys, overall keyboard use and their concomitant behavior during the keyboard sessions was not fully quantified or described.

Goal of the Study

The goal of the current study was to revisit and reexamine the behavioral data generated in Reiss and McCowan (1993) to quantify and describe the dolphins' keyboard usage, learning, and behavior over the course of the investigation. In addition, the newly analyzed data was also compared to the previous findings to determine what correlations existed between the acoustic and behavioral results.

History of Related Research

Choice and control. It has been argued by scientists as early as the 1950s that the provision of perceived control is highly beneficial to the welfare of animals in captivity. In one of the first studies to consider this topic, mice were placed in a Skinner box where they were supplied with a lever that would control the illumination of a light (Kish, 1955). When the lever ceased to cause any effect, there was an extinction of the lever pressing behavior in the mice. Later, Kish & Barnes (1961) conducted a similar study where one group of mice was given a moveable lever while a second group (the control group) had a non-moveable lever. The data indicated that the mice that had a moveable lever would spend significantly more time in contact with it than the control group. The authors concluded that "*any* perceptible environmental change may function as a reinforcer" (Kish & Barnes, 1961). In other words, the allowance of some form of control appeared to be reinforcing, in and of itself.

This topic was further examined in a study by Hanson, Larson, and Snowdon (1976), which looked at how control of a stressful stimulus (high intensity noise) would affect the stress levels and behavior of rhesus monkeys. The subjects were tested over two experimental periods, where they were assigned one of four different conditions: control over the noise, no control over the noise, initial control which was then taken away during the second trial phase, and a group that experienced no noise. Unsurprisingly, physiological stress, as indicated by plasma cortisol levels, was found to be highest in the animals with no control over the negative stimulus, while those with control during both testing periods had the lowest levels. Interestingly, the monkeys who had been given control over the stimulus but had it subsequently taken away showed similar stress levels during the second experimental period as the subjects that had never been given control. Differences in behavior were also seen, relative to which condition the individual was in. Monkeys who had control taken away demonstrated higher amounts of aggression than those in the other conditions; meanwhile, subjects with no control during any part of the experimental periods displayed fewer socially-directed behaviors.

More recently, additional evidence revealing the importance of choice and control has emerged. The provision of choice and control has been shown to reduce stress (Owen, Swaisgood, Czekala, & Lindburg, 2005), increase activity levels with fewer occurrences of undesirable behaviors (Ross, 2006), and allow individuals to cope more effectively in stressful situations (Carlstead & Shepherdson, 1994). Conversely, loss or lack of perceived control appears to result in higher stress levels and an increase in agonistic behaviors.

Artificial languages and interactive systems. Often, the research into non-human animals' cognitive abilities ends up exploring some aspect of choice and control. Beginning in the 1970s, a number of studies were conducted that employed verbal/gestural signs as well as symbols to create artificial languages. These ultimately served as a window into understanding more about an animal's cognition, particularly language acquisition and comprehension, while also giving the animals some degree of control. Signs and symbols within the artificial languages often represented not just objects but also various properties (e.g. size, color) and actions (Herman, Richards, & Wolz, 1984; Schusterman, Krieger, & Johnson, 1983). As a result, the use of such signs and symbols allowed animals to communicate much more effectively with humans and potentially gave them the opportunity to request specific rewards. Schusterman and Krieger (1986), for instance, investigated how object sizes were understood and generalized by a California sea lion (*Zalophus californianus*). First, the subject had been trained to understand gestures made by her trainers that denoted particular objects, adjectives, and actions. Then, blind-folded trainers requested that a specific action be performed using either a small or large ball. During the trials that followed, the standard small or large balls were replaced with balls of other sizes; the subject was then asked to perform actions on the smaller or larger of the balls present. Data indicated that the sea lion was able to accurately transpose her understanding of "small" and "large" to various ball sizes. Other species, such as horses (Hangii, 2003) and African grey parrots (Pepperberg & Brezinsky, 1991) have shown an analogous capacity to transpose size classes. In addition, syntax is often a salient property, with non-human animals distinguishing between actions or items based on the order in which the symbols or gestures are given (Herman, 1986; Schusterman & Krieger, 1986). Some species will even attend to invented grammar rules, displaying distinct reactions dependent on if they perceive a "correct" sequence or if they notice a violation of the grammatical rules (Herbranson & Shimp, 2003; Wilson et al., 2013).

A noteworthy phenomenon that has thus far been observed and studied in only a few species is spontaneous symbol acquisition: the learning of symbol meanings without prior explicit training (such as the use of operant training methods) and employing them in appropriate contexts. One species that has demonstrated spontaneous symbol acquisition is the bonobo (*Pan paniscus*). A long-term study by Savage-Rumbaugh, McDonald, Sevcik, Hopkins, & Rubert (1986) revealed that *P. paniscus* might indeed have the capacity to learn symbols without explicit training, instead learning by watching conspecifics. Starting from a young age, the two subjects in the study were exposed to an array of symbols which were used to signify a wide range of words, including items, verbs, locations, and adjectives. Neither of the subjects was trained to recognize or use the visual symbolic system; instead, they were simply present when other apes, such as their mothers, were utilizing the symbols. Yet, both subjects began to display an understanding of these symbols and quickly started making use of them in appropriate situations, regardless of what order the symbols were initially placed in. Moreover, the subjects began to use multi-symbol "utterances" early in the study, leading to one subject, Kanzi, producing over 2,500 combinations, approximately 30% of which were only used once. Researchers pointed out that Kanzi would sometimes go off by himself with the list of symbols and appear to practice their usage, pointing to the symbol then performing the action or gathering the item he had indicated. Furthermore, Kanzi began to spontaneously request actions where he, himself, was not the subject nor the recipient of the action. In summary, this pivotal study became one of the first to uncover spontaneous symbol acquisition by a non-human animal through a rigorous scientific procedure.

In addition to these remarkable findings, it is also important to remark upon how technology was successfully implemented within this pioneering study. The subjects interacted with a keyboard that lit up when a symbol was touched and integrated a speech synthesizer that would verbalize the corresponding word (Savage-Rumbaugh et al., 1986). The combination of these components created an interactive interface that gave both auditory and visual feedback when utilized.

Related dolphin studies. The bottlenose dolphin (*Tursiops truncatus*) is another notably intelligent species that has also been given the opportunity to interact with such systems and has appeared to exhibit spontaneous symbol acquisition. Bottlenose dolphins are highly social mammals that live in fission-fusion societies, in which individuals form groups varying in composition on a regular basis (Mann, Connor, Tyack, & Whitehead, 2000), and maintain long-lasting social relationships (Lusseau, Schneider, Boisseau, Haase, Slooten, & Dawson, 2003). Additionally, they show cognitive capabilities comparable to great apes (Marino et al., 2007).

Not surprisingly, bottlenose dolphins, both in captivity and the wild, have been the subjects of extensive behavioral and cognitive studies. Referred to as the "cognitive cousins to great apes" (Herman, 1980), bottlenose dolphins have displayed both behavioral and cognitive complexity including a proclivity for vocal imitation (McCowan & Reiss, 1997; Reiss, McCowan, & Marino, 1997; Tyack, 1986) and have demonstrated instances of observational learning (Adler & Adler, 1978). Likewise, this species has exhibited comprehension of artificial gestural languages (Richards et al., 1984), attending to gesture order and modifiers (Herman et al., 1984). Later studies have additionally uncovered evidence of tool use (Smolker, Richards, Connor, Mann, & Berggren, 1997), cultural transmission of certain behaviors (Krützen, Mann, Heithaus, Connor, Bejder, & Sherwin, 2005; Kuczaj, Makecha, Trone, Paulos, & Ramos, 2006), and the capacity for mirror self-recognition (Reiss & Marino, 2001).

To investigate the cognition of bottlenose dolphins, as well as the impact of choice and control on learning in this species, Reiss and McCowan (1993) originally conducted a three-year, longitudinal study with two goals: to investigate and document dolphin vocal learning abilities and to assess how dolphins would utilize an interactive system that afforded them choice and control in obtaining objects and activities. In order to do this, an underwater keyboard was created and presented to a social group of four *T. truncatus*, in a aquarium context at Marine World Africa, in California. The social group was comprised of two adult female dolphins (approximately 20 years of age and 9 years of age) and their 11 month old male offspring. None of the dolphins were given any explicit training utilizing the keyboard; rather, they were given access to the apparatus during 30-minute sessions two to three times per week and were free to use the keyboard at will. It is important to note that the older females chose not to use the keyboard; therefore, the study and analysis of behavior focused solely on the two male offspring, Pan and Delphi. Reiss and McCowan (1993) reported that the two male dolphins exhibited vocal learning as well as spontaneous imitation and productive use of the novel computer-generated whistles. Within the study, mimicry was defined as the occurrence of a whistle facsimile "immediately follow[ing] the computer-generated whistle (the model sound)… if it occurred within 0.5 s of the computer-generated whistle." Conversely, production was defined as the occurrence of a facsimile that "did not immediately follow the computer-generated whistle… included facsimiles that preceded key hits by the dolphins or that occurred in such contexts as toy play, dolphin-dolphin interactions, or solitary swimming during keyboard session" (Reiss & McCowan, 1993).

Two types of keyboard sessions were conducted: Free Choice Fixed (FCF) and Free Choice Randomized (FCR). In the former, keys remained in the same position throughout the session; this condition was only used for 38 sessions in Year 1, after which it was discontinued. In the FCR condition, the locations of the keys were changed every minute throughout the course of the session. The keys were placed in predetermined positions on the keyboard, which were pseudorandomized per session. In other words, each key was placed in every position being used on the keyboard an approximately same number of times. When a dolphin hit a key, a computer generated item-specific whistle would sound after which the dolphin would be given the corresponding item or activity. A selection of keys were utilized through the course of the study, each with a different shape and whistle label, that represented a specific reward. Potential rewards consisted of a ball, fish, rub, ring, disk, or ring float. An important characteristic of this study was that all of the reinforcers were intrinsic, defined as rewards that "have the closest possible link between labels or concepts to be learned and… the object to which the label or concept refers" (Pepperberg, 2017). While it was less researched at the time of the Reiss and McCowan (1993) study, it has since been found that intrinsic rewards are significantly more effective for teaching artificial languages than extrinsic rewards, reinforcers that do not correspond with the label (e.g. teaching the word "milk" but being rewarded with a cookie; Pepperberg, 2017).

One of the most important findings reported in Reiss and McCowan (1993) was the demonstration of spontaneous vocal mimicry and productive use of the item-specific whistles by the two dolphins. The dolphins began to mimic the model whistles after significantly fewer exposures than did dolphins that were explicitly trained to mimic such sounds (Richards et al., 1984; Sigurdson, 1993). While mimicry was higher than production in the study's first year, the second year of data collection revealed very different results, with over 1,000% more production relative to mimicry (p = .0001; Reiss & McCowan, 1993). Moreover, the production of these facsimiles of the model sounds always occurred in appropriate contexts, such as when a dolphin was approaching or playing with the corresponding item or prior to the dolphin pressing the corresponding key. A surprising discovery was also made: during the second year of the study, the dolphins created and began using a combined “Ring-Ball” whistle when a dolphin was playing with both a ball and ring at the same time (which was termed "multi-toy play").

Although acoustic and behavioral data was collected concurrently and key use was analyzed on a daily basis, much of the focus was placed on the former rather than the latter. Therefore, in the present study I analyzed the data from the Reiss and McCowan (1993) study to explore the dolphins' behavior and use of the keyboard. In addition to the two years included in the original publication, unpublished data from the third year were analyzed to document how the dolphins' use of the keyboard progressed over time. Four main questions formed the basis of the current study, each of which consisted of specific variables that were examined:

1. What were the patterns of keyboard use?
2. Did the dolphins show evidence of understanding the contingencies of keyboard use?
3. What were the dolphins’ patterns of multi-toy play?
4. How did the dolphins interact with each other during the keyboard sessions?

First, of foremost importance was determining how the dolphins utilized the keyboard and if they showed an understanding of its contingencies. To do so, first key hits were analyzed, as well as total hits for each key and position, to provide a better idea of whether the animals understood the key contingencies or if they were choosing items at random. Based on the existing literature, we hypothesized that the dolphins would exhibit a change in keyboard usage over time. More specifically, we expected to observe a learning curve where the dolphins would initially prefer certain key positions as they explored the contingencies between the keyboard symbols and rewards. Furthermore, we predicted that the use of the keyboard and the dolphins' subsequent behavior would correspond with the vocal results found in the prior publication, such as key hits decreasing over time as mimicry decreased.

Secondly, it was vital to determine how the dolphins were responding to the items, such as if the dolphins were accepting the items that corresponded with the key they hit, or if they were rejecting said items. In other words, did they begin to use the keyboard to request preferred items? We anticipated that after the contingencies had been learned, the dolphins tracked and made use of the symbols that represented their preferred outcome regardless of where the key was positioned on the keyboard. We also predicted that they played/accepted these items more than they rejected them.

The third question sought to evaluate the dolphins' use of multiple toys at once, which had been obtained using the keyboard. Previously it had been reported that the dolphins had created a "Ring-Ball" combination whistle but the actual instances of double-toy play had not been included. Therefore, we predicted that the rate of production of the Ring-Ball whistle would correlate with the frequency of Ring and Ball key hits as well as of Ring-Ball double-toy play.

Lastly, we assessed the dolphin's interactions with each other during the keyboard sessions: the behaviors seen during this time could provide more information about how each dolphin used the keyboard and might allow us a more intimate look at the potential dominance trends between the two calves. Because researchers have found male dolphins to have flexible dominance patterns (Samuels & Gifford, 1997), we did anticipate that the data would show shifts in dominance between the two male dolphins over the three years of data collection. However, no further predictions about how dominance might have impacted keyboard usage and the calves' behavior were made.

Method

Subjects and Facilities

The subjects of the Reiss and McCowan (1993) study, and therefore the present study, were two young captive-born, male bottlenose dolphins (*Tursiops truncatus*). At the time that the study began, both males (Pan and Delphi) were 11 months of age and lived in a social group together, along with their mothers. It should be noted that at the onset of the study, the young males were still nursing and had not begun to eat fish. Neither Pan nor Delphi had received formal training before the onset of this study with the exception that they were experienced in positioning themselves next to their mothers at specific pool locations during feeding contexts.

All four dolphins resided together in dedicated research pools at Marine World Africa USA (MWAUSA) in Redwood City, CA. Their enclosure was a 2.13m (7ft) deep kidney-shaped pool that held 215,769L (57,000gal) of treated bay water. At the end of the first year of data collection (August 1985), MWAUSA and, thus, the dolphins were relocated to Vallejo, CA and moved into larger research pools. The dolphins' new enclosure consisted of two connected pools, both of which were 4.88m (16ft) deep and 15.24m (50ft) in diameter. Beginning just prior to the move, there was a hiatus of approximately two years during which time the dolphins did not have access to the keyboard. In July 1987, the second year of keyboard research commenced.

Materials

Underwater keyboard design features. The keyboard system used in Reiss and McCowan (1993) consisted of a 53.34cm (21 in.) x 60.96cm (24 in.) base, 8.89cm x 8.89cm (3 ½ in. x 3 ½ in.) key pads, and 1.27cm (1/2 in.) visual forms, all of which were constructed using polyvinyl-chloride (PVC) plastic. The base was painted dark grey and mounted on PVC pipe so that the apparatus could be affixed to the concrete wall of the dolphin pool. The visual forms (hereafter referred to as symbols) were cut from 7.62cm (3 in.) x 7.62cm (3 in.) squares of PVC and each one was a distinct shape, designed to “share few if any similar features” (Reiss & McCowan, 1993). Each symbol represented a specific item or activity that would be offered to the dolphins if they pressed the symbol, activating the key (the symbol position was referred to as the "key position"). Keys were painted black to offset the white symbols, the latter were affixed and locked in place to the keys by a vertical stainless steel pin that allowed the human operator to reposition keys as needed. There were nine total positions where keys could be placed, which were numbered from 0 (top left corner) to 8 (bottom right corner; see Figure 1). The use of the nine positions where keys could be placed on the keyboard by the researchers differed during each data collection period. More specifically, Year 1 Free Choice Fixed (FCF) was the only period when all positions (0-8) were used. In Year 1 Free Choice Randomized (FCR), only the top row (Positions 0-2) were utilized, while in Year 2 FCR, keys were mainly placed in the top row (Positions 0-2) and for approximately

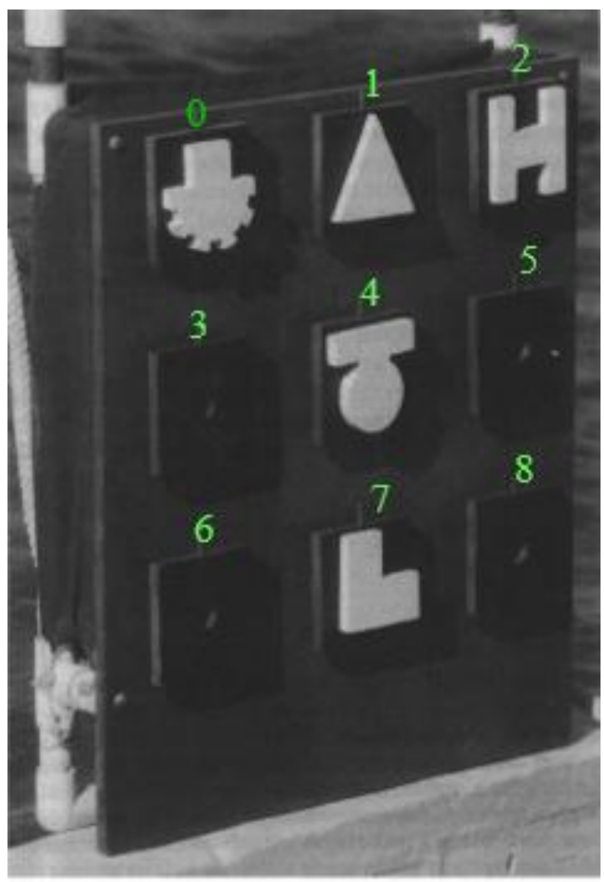


Figure 1. The underwater keyboard.

Figure 1. Underwater keyboard with position numbers labeled in green (Reiss & McCowan, 1993).

a quarter of the sessions the middle row (Positions 3-5) was used as well. For the duration of Year 3 FCR, the researchers primarily used the top two rows of the keyboard for ease of symbol placement. Additionally, the keys that were available on the keyboard changed over the course of the study: for the list of keys that were included during each period, see Table 1.

Table 1

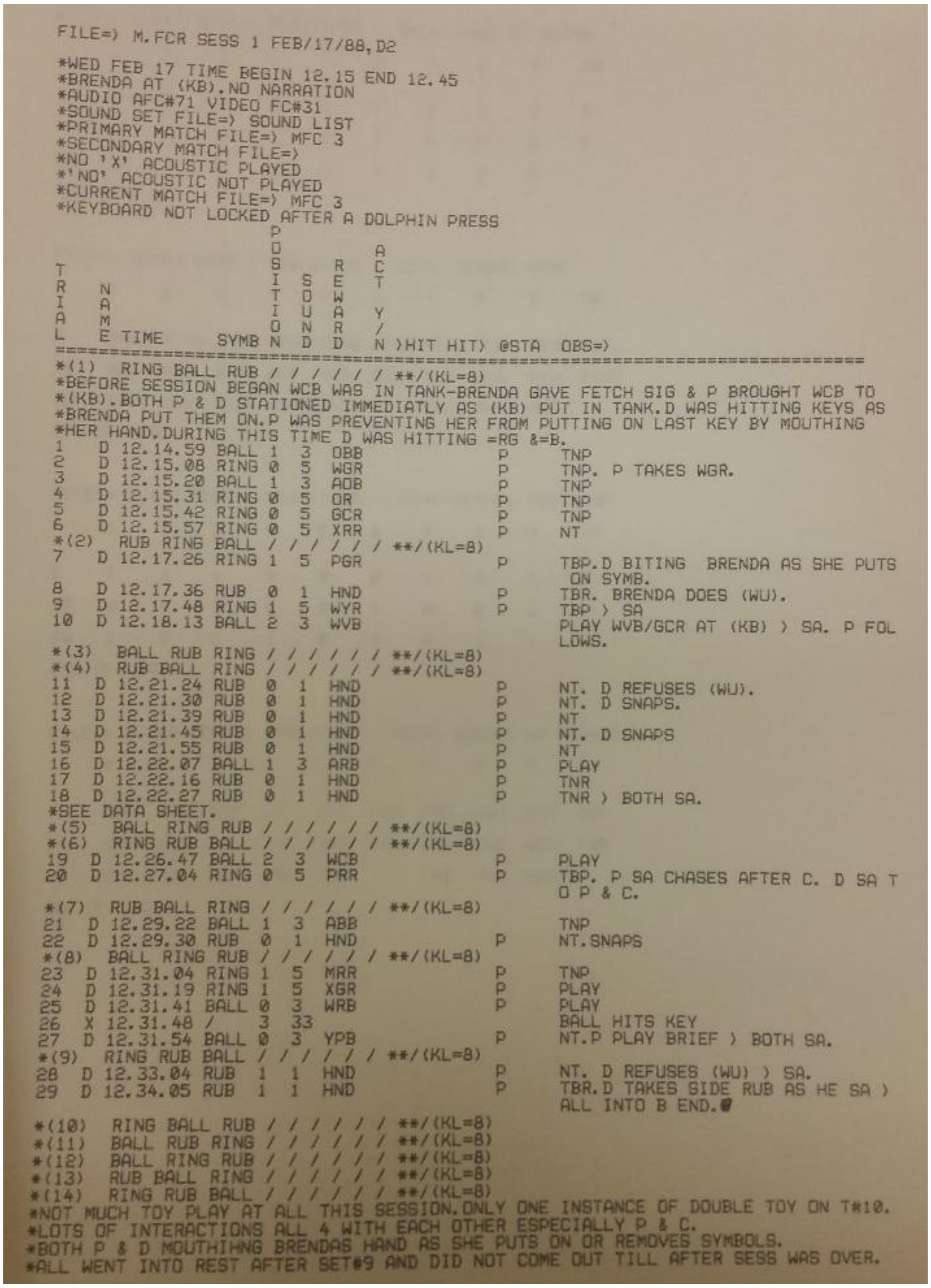
Total Number Of Sessions That Rewards Were Available per Period

Data Collection Periods	**Rewards**					
	Ball	Fish	Rub	Ring	Disk	Ring Float (R Float)
Year 1 FCF (38)	38	29	38	0	0	0
Year 1 FCR (22)	22	3	14	16	0	0
Year 2 FCR (65)	65	0	65	65	0	0
Year 3 FCR (37)	37	0	37	37	36	36

Note. Numbers in parentheses are the total number of sessions during that period.

Procedures

Data collection. Data collection spanned over the course of three years, with four data collection periods: July 1984-October 1984 (Year 1 FCF), November 1984-August 1985 (Year 1 FCR), June 1987-April 1988 (Year 2 FCR), and February 1989-December 1989 (Year 3 FCR). All sessions were documented via video and audio recordings (for detailed information about the experimental procedures, see Reiss & McCowan, 1993). Behavioral data was also systematically recorded by hand by a trained observer throughout the course of each session; these were later transcribed digitally. Data sheets contained the time of the key hit, the individual that hit the key (actor), the key used, the position that the key was in, the specific reward given, acceptance or rejection of the reward by the actor, individuals stationed at the keyboard that were not actively using the keyboard during that instance, and relevant behavioral notes (for a sample data sheet, see Figure 2).



```
FILE=) M.FCR SESS 1 FEB/17/88,D2

*WED FEB 17 TIME BEGIN 12.15 END 12.45
*BRENDA AT (KB).NO NARRATION
*AUDIO AFC#71 VIDEO FC#31
*SOUND SET FILE=) SOUND LIST
*PRIMARY MATCH FILE=) MFC 3
*SECONDARY MATCH FILE=)
*NO 'X' ACOUSTIC PLAYED
*'NO' ACOUSTIC NOT PLAYED
*CURRENT MATCH FILE=) MFC 3
*KEYBOARD NOT LOCKED AFTER A DOLPHIN PRESS

TRIAL NAME TIME SYMB POSITION SOUND REWARD ACT Y/N )HIT HIT) @STA OBS=)
==========================================================================
*(1)   RING BALL RUB / / / / / / **/(KL=8)
*BEFORE SESSION BEGAN WCB WAS IN TANK-BRENDA GAVE FETCH SIG & P BROUGHT WCB TO
*(KB).BOTH P & D STATIONED IMMEDIATLY AS (KB) PUT IN TANK.D WAS HITTING KEYS AS
*BRENDA PUT THEM ON.P WAS PREVENTING HER FROM PUTTING ON LAST KEY BY MOUTHING
*HER HAND.DURING THIS TIME D WAS HITTING =RG &=B.
1   D 12.14.59 BALL 1  3  OBB          P    TNP
2   D 12.15.08 RING 0  5  WGR          P    TNP. P TAKES WGR.
3   D 12.15.20 BALL 1  3  AOB          P    TNP
4   D 12.15.31 RING 0  5  OR           P    TNP
5   D 12.15.42 RING 0  5  GCR          P    TNP
6   D 12.15.57 RING 0  5  XRR          P    NT
*(2)   RUB RING BALL / / / / / / **/(KL=8)
7   D 12.17.26 RING 1  5  PGR          P    TBP.D BITING  BRENDA AS SHE PUTS
                                             ON SYMB.
8   D 12.17.36 RUB  0  1  HND          P    TBR. BRENDA DOES (WU).
9   D 12.17.48 RING 1  5  WYR          P    TBP ) SA
10  D 12.18.13 BALL 2  3  WVB               PLAY WVB/GCR AT (KB) ) SA. P FOL
                                            LOWS.
*(3)   BALL RUB RING / / / / / / **/(KL=8)
*(4)   RUB BALL RING / / / / / / **/(KL=8)
11  D 12.21.24 RUB  0  1  HND          P    NT. D REFUSES (WU).
12  D 12.21.30 RUB  0  1  HND          P    NT. D SNAPS.
13  D 12.21.39 RUB  0  1  HND          P    NT
14  D 12.21.45 RUB  0  1  HND          P    NT. D SNAPS
15  D 12.21.55 RUB  0  1  HND          P    NT
16  D 12.22.07 BALL 1  3  ARB          P    PLAY
17  D 12.22.16 RUB  0  1  HND          P    TNR
18  D 12.22.27 RUB  0  1  HND          P    TNR ) BOTH SA.
*SEE DATA SHEET.
*(5)   BALL RING RUB / / / / / / **/(KL=8)
*(6)   RING RUB BALL / / / / / / **/(KL=8)
19  D 12.26.47 BALL 2  3  WCB          P    PLAY
20  D 12.27.04 RING 0  5  PRR          P    TBP. P SA CHASES AFTER C. D SA T
                                            O P & C.
*(7)   RUB BALL RING / / / / / / **/(KL=8)
21  D 12.29.22 BALL 1  3  ABB               TNP
22  D 12.29.30 RUB  0  1  HND          P    NT.SNAPS
*(8)   BALL RING RUB / / / / / / **/(KL=8)
23  D 12.31.04 RING 1  5  MRR          P    TNP
24  D 12.31.19 RING 1  5  XGR          P    PLAY
25  D 12.31.41 BALL 0  3  WRB          P    PLAY
26  X 12.31.48 /    3  33                   BALL HITS KEY
27  D 12.31.54 BALL 0  3  YPB          P    NT.P PLAY BRIEF ) BOTH SA.
*(9)   RING RUB BALL / / / / / / **/(KL=8)
28  D 12.33.04 RUB  1  1  HND          P    NT. D REFUSES (WU) ) SA.
29  D 12.34.05 RUB  1  1  HND          P    TBR.D TAKES SIDE RUB AS HE SA )
                                            ALL INTO B END.
*(10)  RING BALL RUB / / / / / / **/(KL=8)
*(11)  BALL RUB RING / / / / / / **/(KL=8)
*(12)  BALL RING RUB / / / / / / **/(KL=8)
*(13)  RUB BALL RING / / / / / / **/(KL=8)
*(14)  RING RUB BALL / / / / / / **/(KL=8)
*NOT MUCH TOY PLAY AT ALL THIS SESSION.ONLY ONE INSTANCE OF DOUBLE TOY ON T#10.
*LOTS OF INTERACTIONS ALL 4 WITH EACH OTHER ESPECIALLY P & C.
*BOTH P & D MOUTHIHNG BRENDAS HAND AS SHE PUTS ON OR REMOVES SYMBOLS.
*ALL WENT INTO REST AFTER SET#9 AND DID NOT COME OUT TILL AFTER SESS WAS OVER.
```

Figure 2. Sample transcribed data collection sheet.

Data analysis. Data to be analyzed were split into four periods: Year 1 FCF, Year 1 FCR, Year 2 FCR, and Year 3 FCR. This first period was further subdivided into two subsets: the initial sessions in which there was a key representing fish on the keyboard and the remaining sessions in which access to the Fish key was discontinued. In the original study's data analysis, the researchers generated frequency of occurrence matrices for key hits and positions for each session; these results were included in the analyses for the present study. All data sheets were re-transcribed, along with the behavioral notes, into Microsoft Excel software for additional analysis (both quantitative and qualitative). Descriptive statistics were calculated using Excel, including totals and averages, and values were compared between and within subjects.

Overall keyboard use. The percentage of sessions in which each dolphin participated, total number of key hits per position and per item, average number of key hits per session (only using the number of sessions that a particular individual used the keyboard), and first keys hit per session were assessed for each dolphin. For every variable, both values as well as percentages were determined; percentages were calculated using only the session that a particular key was available on the keyboard. Line graphs depicting a dolphin’s key hits, position hits, and overall hits over the course of a data period’s sessions were created in Excel.

Acceptance/rejection of rewards. In order to ascertain if the dolphins were showing evidence of understanding the keyboard contingencies, responses by the actor to the rewards given after a key hit were evaluated. More specifically, acceptance and rejection rates of rewards were quantified, as well as of the response “touch no play” (TNP). TNP was defined as when an item/reward was briefly touched by the actor when it was offered, but was not further interacted with before the next key hit. It should be noted that TNP was not recorded consistently until Year 2 FCR (which began on 1/13/88) and, as such, was not present in the analyses for Year 1 FCF and Year 1 FCR. Percentages for TNP, therefore, were calculated only using the number of sessions that followed this date. Overall values along with the frequency, in percentage, of all response types were calculated for each dolphin. Line graphs were created in Excel for each dolphin and data collection period representing acceptance and rejection rates of rewards over time. For the purposes of some of the graphs, acceptance rates consisted of the values for Accept/Play and TNP combined, since the latter did not indicate an outright rejection by the dolphin.

Multi-toy play. All instances of multi-toy play, separated into double (two item) and triple (three item) toy play, during the course of a session (as noted on the data collection sheet) was quantified for the two dolphins. These were subsequently analyzed for the frequency that different item combinations were used (i.e. double-toy play could consist of two balls, one ball and one ring, or two rings) and the order in which the items utilized in multi-toy play were obtained via the keyboard. Total values along with percentages were recorded.

Interceptions. Interceptions were defined as instances when a dolphin (interceptor) took a reward after a key was hit by another dolphin (recipient), but before the recipient could accept the reward, or when the interceptor took a reward after the recipient had briefly touched/accepted it. The latter form of interception was noted under the behavioral notes in the data collection sheets. Analyses consisted of total interceptions and the frequency of interception for each key present on the keyboard, per dolphin and per data collection period. Percentage values were also calculated.

Results

A total of 162 sessions were conducted over the course of the three year study, split between four data collection periods: Year 1 FCF (n = 38), Year 1 FCR (n = 22), Year 2 FCR (n

= 65), and Year 3 FCR (*n* = 37). Pan participated in 102 (63%) total sessions (*n* = 31, 22, 15, and 34, for the data collection periods, respectively) while Delphi participated in 109 (67%) sessions (*n* = 12, 22, 45, and 30, respectively).

Year 1

Pan was the first dolphin to interact with the keyboard and his first "true" key hit (i.e. a symbol that was hit hard enough to trigger the keypad) was in Session 8 of Year 1 FCF. This initial hit, which was for Rub in Position 3, took place a little over ten minutes into the session. At the moment of this event, both Pan and his mother, Terry, were at the keyboard location and "stationed" (defined as the dolphin positioning its body in front of the keyboard, with its rostrum facing the keys). Terry remained stationed for 83.33% (*n* = 5) of Pan's key hits during this pivotal session. It should be noted that in the sessions preceding this first hit, Pan had shown orienting toward the keyboard. In Session 6, he had pressed a symbol (Ball in Position 3) but it was not hard enough to trigger the keypad; due to this, it was not considered a "true" key hit.

Delphi, on the other hand, began to use the keyboard during Session 27 of Year 1 FCF, which was 19 sessions after Pan. Prior to this, Delphi had stationed at the keyboard and appeared to be observing Pan's key usage. In Session 27, Delphi had showed quite a bit of interest in the keyboard, remaining at station for 41.03% of all Pan's key hits during this session before Delphi's first hit. When stationed with Pan, Delphi would frequently touch his rostrum to Pan's side. A minute before Delphi's first key hit, Pan hit the Fish key and the researchers observed him engaging in beak-genital contact with Delphi while Pan was holding the reward (a herring) in his beak. The first keyboard activity that followed this behavior was Delphi's first key hit of the study: the Rub key located in Position 0. This occurred around 31.5 minutes after the start of the session.

Pan. Pan showed similar rates of keyboard usage, signified by the average number of key hits per session, over both periods (*M* = 31.00 in Year 1 FCF; *M* = 30.91 in Year 1 FCR).

Position. Pan did not display a position preference during Year 1 FCF. During Year 1 FCR, Pan showed a tendency toward hitting keys placed in Position 0 (54.56% of all keys hit).

Key use. When the Fish key was present, Pan displayed a clear preference for it: of all key hits during sessions with the Fish key accessible, 85.93% in Year 1 FCF and 84.77% in Year 1 FCR were for Fish. This inclination was also apparent in first key hits for both periods: 83.33% in Year 1 FCF and 66.67% in Year 1 FCR of first key hits were for Fish. When the Fish key was removed after three sessions in Year 1 FCR, no key preference was seen.

Blank key hits. Pan hit very few blank keys overall in Year 1 FCR (*n* = 11; 1.14% of all key hits), with none in Year 1 FCR. The first example of Pan hitting a blank key was during Session 15 of Year 1 FCF; this was the first session when the Fish key was removed from the keyboard. As Pan approached the keyboard, he began shaking his head from side to side with an open mouth. He then swam to the bottom of the pool, grabbed a previously discarded fish, and returned to the keyboard. With the fish still in his mouth, Pan pressed it against a blank key. The behavior was repeated three times in quick succession, resulting in three more blank key hits. When the researchers did not respond to Pan pressing a fish against a blank key, however, he discontinued this behavior.

Delphi. Delphi had higher rates of keyboard usage in Year 1 FCF (*M* = 39.75) than in Year 1 FCR (*M* = 23.00).

Position. Delphi did not demonstrate a position preference during Year 1 FCF, but did during Year 1 FCR. At this time, a preference for Position 0 was observed (55.14% of all keys hit).

Key use. Delphi also showed a preference for the Fish key when it was available in Year 1 FCF (57.56% of key hits during sessions with the Fish key) and Year 1 FCR (50.32%), though to a lesser extent than Pan. There was no discernable key preference during Year 1 FCR once the Fish key was taken off, however. Interestingly, the data for first key hits indicated a slightly different pattern in Year 1 FCR. While Fish (50.00%) was the key that was hit first most often in Year 1 FCF, in Year 1 FCR Ring was hit first much more frequently than any of the other keys (52.94% of all first key hits), even during sessions when Fish was present.

Blank key hits. Delphi did have a number of blank key hits in Year 1 FCF (n = 59; 12.37% of all key hits) and, to a lesser degree, in Year 1 FCR (n = 10; 1.98% of all key hits). These occurred when the Fish key was accessible on the keyboard as well as when it was not.

Year 2

After the two year hiatus between Year 1 FCR and Year 2 FCR, during which the dolphins were transferred to the new facility, Delphi was the first of the dolphins to resume using the keyboard. The first key hit was a blank key located in Position 6 which occurred during Session 5; the first non-blank key press was for Ball (Position 5) during Session 8. Meanwhile, Pan recommenced using the keyboard during Session 29 but began actively hitting keys (i.e. more than one key hit per session) in Session 55. Pan's first hit, which occurred in Session 29, was for Ball (Position 1).

Pan. Average key hits per session indicated a much lower rate of keyboard use for Pan (M = 17.67 key hits per session) than in any other data collection period.

Position. As with Year 1 FCR, Pan showed a Position 0 preference (43.02% of all keys hit).

Key use. No key preferences were observed for Pan during this data collection period.

Blank key hits. Pan did not have any blank key hits during Year 2.

Delphi. Delphi's keyboard usage in Year 2 FCR (*M* = 26.11) was one of the highest seen by Delphi in the study, second only to Year 1 FCF.

Position. No position preferences emerged for Delphi during this period.

Key use. Delphi had almost equal numbers of key hits for Ball (33.79%) and Ring (33.87%), when compared with the third key option, Rub (27.74%); this finding will be discussed in later sections. These corresponded with first key hits, which also indicated roughly equal numbers for Ring (35.56%) and Ball (33.33%).

Blank key hits. In total, 4.60% of all key hits by Delphi in Year 2 FCR were blank keys (*n* = 54), the majority of which took place during two sessions (Sessions 5 and 22). Session 5 was the first instance when Delphi began hitting keys, with 100% of his hits (*n* = 5) being blank keys. After Session 8, which was the first time that Delphi hit a non-blank key in Year 2, there was a period of 14 sessions where no keys were hit. Keyboard activity by Delphi resumed in Session 22, with 75.55% of all key hits being blank keys (*n* = 41). For the remainder of this data collection period, however, only 0.72% of Delphi's hits were blank keys (*n* = 8).

Year 3

From the first session of this year onward, two new keys were added to the already existing choices (which consisted of Ball, Ring, and Rub): these were for Disk and R Float. Keyboard activity by both Pan and Delphi resumed during the first session of Year 3 FCR. The first hit was by Pan, who hit the Rub key located in Position 1. Delphi hit his first key, R Float in Position 5, fifteen seconds later.

Pan. Pan was the dolphin most actively using the keyboard during this period (*M* = 28.24 key hits per session).

Position. As with Year 1 FCF, Pan did not exhibit any position preferences in Year 3 FCR.

Key use. Pan revealed a slight preference for Ball (27.71% of keys hit), although this did not correspond with the data for his first key hits, which indicated a slight preference for R Float (29.41%).

Blank key hits. During Year 3 FCR, 0.52% of all key hits by Pan were blank keys (n = 5).

Delphi. Delphi engaged less with the keyboard in Year 3 FCR than he had in any of the previous periods (M = 12.77 key hits per session).

Position. Delphi did not exhibit any position preferences during this period.

Key use. Year 3 FCR saw almost equal hits by Delphi for Ball (25.33%) and R Float (25.27%). As with Pan, first key hits in Year 3 FCR did not correspond with Delphi's observed overall key preferences. More specifically, R Float was most often the first key hit (30.00%), although Ball was a close second (26.67%).

Blank key hits. Delphi did not have any blank key hits during this period.

Comparison of Key Use

Both total key hits as well as average key hits per session revealed a decrease in keyboard usage by Pan from Year 1 FCF through Year 2 FCR (see Table 2), although Year 3 FCR showed an increase in use. This latter increase, however, never reached the same levels of usage that Pan had presented in Year 1. Conversely, Delphi's data (see Table 2) indicated a much more random pattern of use. Both Pan and Delphi's key use over time is illustrated in Figure 1. It should be noted that when the Fish key was available, average key hits by both dolphins increased. This was especially evident for Pan: average key hit values were much higher when the Fish key was present on the keyboard for both Year 1 FCF (M = 51.82) and Year 1 FCR (M = 50.33) than when the Fish key was not present (*M* = 16.00 and 29.39, respectively). Delphi, too, had higher rates of key usage in Year 1 FCF (*M* = 43.00) and Year 1 FCR (*M* = 52.33) when Fish was present than when it was not (*M* = 33.25 and 19.39, respectively), though to a lesser extent than Pan.

Table 2

Average and Total Key Hits per Period

	Average Key Hits		Total Key Hits	
Data Collection Periods	Pan	Delphi	Pan	Delphi
Year 1 FCF	31.00	39.75	961	477
Year 1 FCR	30.91	23.00	680	506
Year 2 FCR	17.67	26.11	265	1175
Year 3 FCR	28.24	12.77	960	383

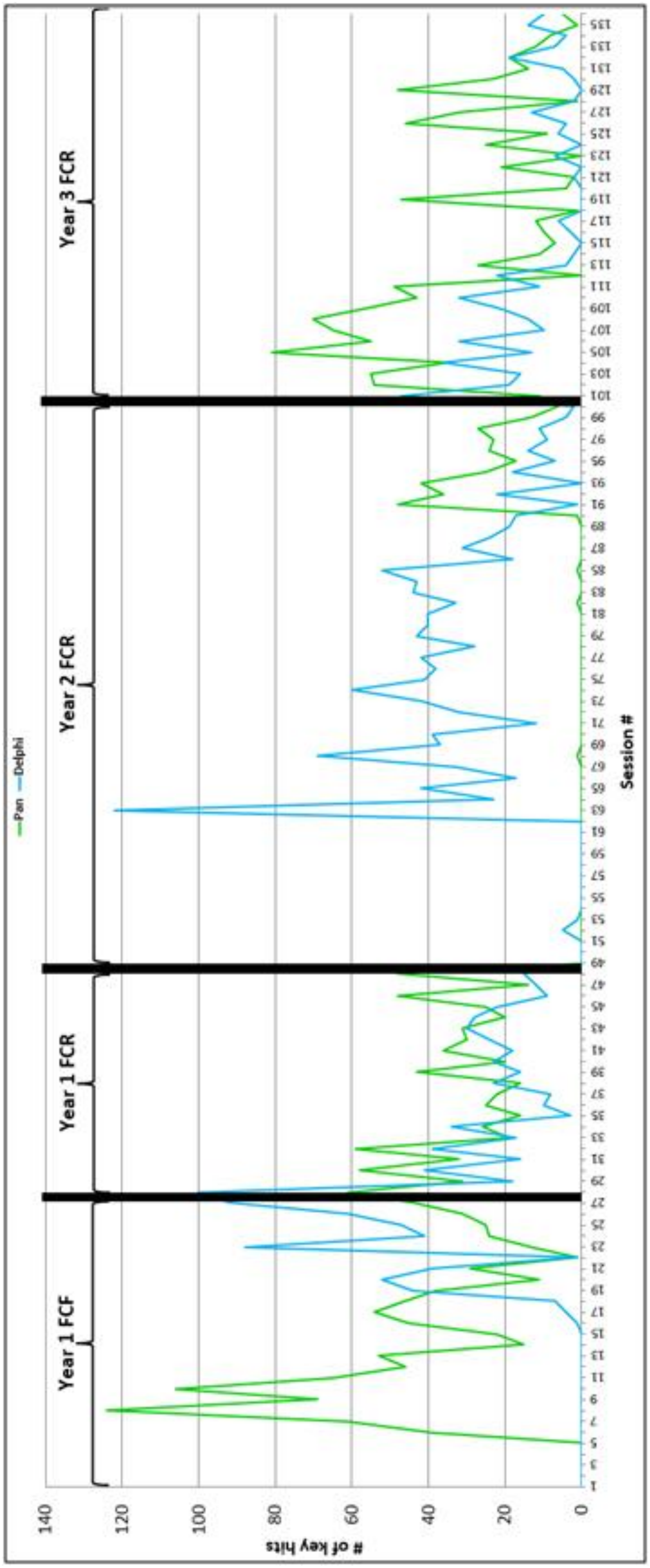


Figure 3. Total key hits per session over time.

Acceptance/Rejection of Rewards

Year 1.

Pan. Overall, Pan accepted most of his rewards during Year 1 FCF and Year 1 FCR (see Table 3): specifically, Ball (96.74% acceptance) and Fish (95.32%) had the highest acceptance rates in Year 1 FCF, while the same items, Fish (100.00%) and Ball (92.02%), were most accepted during Year 1 FCR.

Delphi. Delphi most often accepted rather than rejected offered rewards during Year 1 FCF and Year 1 FCR (see Table 4). During Year 1 FCF, Delphi's most frequently accepted rewards were Fish (97.98% acceptance rate) followed by Ball (86.21%). This pattern continued into the succeeding data collection period, with Fish and Ball having the highest acceptance rates (93.67% and 89.87%, respectively) of the offered rewards in Year 1 FCR.

Year 2.

Pan. During Year 2 FCR, rates of the "Accept" response for two of the three keys, Ball and Ring, dropped considerably (to 38.46% and 37.37%, respectively; see Table 3), while Rub had its highest acceptance rate of any period (97.26%). Year 2 was also when TNP began to be actively recorded; it became the most frequent response by Pan for Ball and Ring in this year.

Delphi. Similarly to Pan, Year 2 FCR revealed a decreasing trend of accepting rewards (see Table 4). However, in contrast to Pan, Delphi did continue to Accept/Play with, rather than TNP or Reject, his rewards in Year 2 FCR, just at a reduced rate as compared to the previous periods. The most frequent response for all three offered rewards (Ball, Ring, and Rub) was "Accept/Play" (43.43%, 53.02%, and 68.62%, respectively).

Year 3.

Pan. During the final year, rates of "Accept" for all rewards, except Rub (73.88% acceptance) and Ball (44.49%), were lower than the other two response types (see Table 3). Instead, rejection rates were highest for: Disk (84.35% rejection), R Float (49.25%), and Ring (56.07%). Even when the responses "Accept/Play" and "TNP" were added together under the all-encompassing term "Accept," both Disk and Ring were rejected more frequently than accepted.

Delphi. Year 3 FCR was the first time period where any item was rejected more than accepted by Delphi (see Table 4). This was the case for three rewards: Disk (76.12% rejection), Ring (59.38%), and R Float (48.94%). With Accept/Play and TNP combined into the category "Accept", the data indicated that Disk and Ring were still more rejected than accepted when offered. Ball and Rub still had the higher Accept/Play rates than TNP or Reject (62.11% and 77.59%, respectively).

Table 3

Responses for Each Item per Period (Pan)

	Year 1 FCF			Year 1 FCR			Year 2 FCR			Year 3 FCR		
Item	A	R	TNP	A	R	TNP	A	R	TNP	A	R	TNP
Ball	96.74%	3.26%	-	92.02%	7.98%	-	38.46%	15.38%	46.15%	44.49%	24.41%	31.10%
Disk	-	-	-	-	-	-	-	-	-	4.08%	49.25%	38.69%
Fish	95.32%	4.68%	-	100.00%	0.00%	-	-	-	-	-	-	-
R Float	-	-	-	-	-	-	-	-	-	12.06%	49.25%	38.69%
Ring	-	-	-	89.90%	10.10%	-	37.37%	24.24%	38.38%	15.03%	56.07%	28.91%
Rub	73.27%	26.73%	-	60.51%	39.49%	-	97.26%	1.37%	1.37%	73.88%	9.70%	16.42%

Note. A = Accept; R = Reject; TNP = Touch No Play.

Table 4

Responses for Each Item per Period (Delphi)

	Year 1 FCF			Year 1 FCR			Year 2 FCR			Year 3 FCR		
Item	A	R	TNP	A	R	TNP	A	R	TNP	A	R	TNP
Ball	86.21%	13.79%	-	89.87%	10.13%	-	43.43%	14.90%	41.67%	62.11%	18.95%	18.95%
Disk	-	-	-	-	-	-	-	-	-	16.42%	76.12%	7.46%
Fish	97.98%	2.02%	-	93.67%	6.33%	-	-	-	-	-	-	-
R Float	-	-	-	-	-	-	-	-	-	21.28%	48.94%	29.79%
Ring	-	-	-	87.93%	12.07%	-	53.02%	22.36%	24.62%	17.19%	59.38%	23.44%
Rub	72.00%	28.00%	-	72.73%	27.27%	-	68.62%	25.85%	5.54%	77.59%	5.17%	17.24%

Note. A = Accept; R = Reject; TNP = Touch No Play

Multi-Toy Play

Multi-toy play was first recorded in Year 1 FCR (Session 9), when Pan exhibited Ball-Ball double-toy play. Multi-toy play by both Pan and Delphi continued throughout the remainder of the study. However, individual instances of multi-toy play were not consistently recorded during Year 3 FCR and, therefore, were not able to be included in the analyses.

Pan. Pan engaged in roughly equal amounts of double-toy play in Year 1 FCR (n = 36) and in Year 2 FCR (n = 37). Likewise, Pan had approximately the same number of triple-toy play bouts in Year 1 FCR (n = 2) and Year 2 FCR (n = 3). With regards to double-toy play, Pan's most frequent combination was Ring-Ball, accounting for 61.11% of double-toy play occurrences in Year 1 FCR and 75.68% of all cases in Year 2 FCR (see Table 5). Since triple-toy play was relatively uncommon, trends, if any, were difficult to discern.

Table 5

Double-Toy Play Combinations (Pan)

	Double-Toy Combinations			
Data Collection Periods	Ball/Ball	Ball/Ring	Ring/Ring	Total
Y1 FCR	11	22	3	36
Y2 FCR	7	28	2	37

Delphi. Over the two periods that multi-toy play was recorded, Delphi showed a three-fold increase in double-toy play from Year 1 FCR (n = 35) to Year 2 FCR (n = 112); an increase in triple-toy play from Year 1 FCR (n = 0) to Year 2 FCR (n = 6) was also observed. The most frequent combination of toys for double-toy play in both years was Ring-Ball, accounting for 55.88% of all instances in Year 1 FCR and 81.25% of all occurrences in Year 2 FCR (see Table 6).

Table 6

Double-Toy Play Combinations (Delphi)

	Double-Toy Combinations			
Data Collection Periods	Ball/Ball	Ball/Ring	Ring/Ring	Total
Y1 FCR	14	19	1	34
Y2 FCR	17	91	4	112

Interceptions

In total, 67 examples of interceptions were recorded, performed by three of the four dolphins in the social group: Pan (*n* = 51; see Table 7), Delphi (*n* = 9; see Table 8), and Pan's mother, Terry (*n* = 7). The first recorded instance of an interception during the study was by Delphi in Session 14.

Year 1.

Pan. In Year 1 FCF, Pan was observed multiple times intercepting from Delphi (*n* = 5): these comprised of Ball (*n* = 3), Fish (*n* = 1), and Rub (*n* = 1) rewards. Pan's first interception was during Session 32, after having been the recipient in seven cases prior to this (six performed by Delphi and one by Terry), and was the only interception during this session. In this event, a Ball reward was intercepted from Delphi. In the following period, Year 1 FCR, there was an increase in interceptions by Pan (*n* = 14). All of these instances, except for one, were intercepting Fish from Delphi. The majority of reward interceptions by Pan at this time took place over the course of three sessions, since only three sessions included the Fish key in Year 1 FCR. Once the Fish key was removed, Pan only once intercepted a reward from Delphi (Rub; see Table 7).

Delphi. The first recorded interception of the study occurred in Year 1 FCF, when Delphi intercepted a Fish reward from Pan. At this point, Delphi had not yet begun to utilize the keyboard but had been observed stationing and observing Pan's use. During the key presses directly before this first interception, the behavioral notes indicated that Pan had been playing with his rewards (all of which were fish and received from pressing the Fish key), including tossing these fish back at the keyboard. All of the interceptions by Delphi for this data collection period, Year 1 FCF (*n* = 6), were of fish and all were intercepted from Pan. In Year 1 FCR, however, there was a decrease in the number of interceptions by Delphi (*n* = 1): this one instance was for Ball, which Delphi intercepted from Pan (see Table 8).

Terry. Terry, who did not appear to be interested in using the keyboard itself, intercepted five rewards in Year 1 FCF and two in Year 1 FCR. The rewards she intercepted in Year 1 FCF were Rub (*n* = 3) and Ball (*n* = 2); in all cases except one, she targeted her calf, Pan. In Year 1 FCR, Terry performed two interceptions of Rub rewards being received by Pan. After this period, though, no more interceptions by Terry were observed.

Year 2.

Pan. After the two-year hiatus, interceptions by Pan nearly doubled from the previous data collection period (from *n* = 14 to *n* = 27). Although Pan did not display a proclivity for any specific reward during Year 1 FCR after the Fish key was removed, a clear preference emerged in Year 2 FCR: Ball (*n* = 15) and Ring (*n* = 11) were almost equally intercepted from Delphi by Pan (see Table 7).

Delphi. Delphi only had one interception in this period, which targeted Pan and his reward, Ball (see Table 8).

Year 3.

Pan. In Year 3 FCR, Pan had fewer interceptions (*n* = 5) than the previous year. The majority were for Ball (*n* = 3), with only one interception each for R Float and Rub; all of these rewards had been intercepted from Delphi (see Table 7).

Delphi. The number of interceptions by Delphi in Year 3 FCR remained the same as the previous two data collection periods (*n* = 1). This sole interception by Delphi targeted Pan for a Disk reward (see Table 8).

Table 7

Interceptions per Period and Item (Pan)

	Rewards						
Data Collection Periods	Ball	Disk	Fish	R Float	Ring	Rub	Total
Y1 FCF	3	-	1	-	-	1	5
Y1 FCR	0	-	13	-	0	1	14
Y2 FCR	15	-	-	-	11	1	27
Y3 FCR	3	0	-	1	0	1	5
Total	21	0	14	1	11	4	51

Table 8

Interceptions per Period and Item (Delphi)

	Rewards						
Data Collection Periods	Ball	Disk	Fish	R Float	Ring	Rub	Total
Y1 FCF	0	-	6	-	-	0	6
Y1 FCR	1	-	0	-	0	0	1
Y2 FCR	1	-	-	-	0	0	1
Y3 FCR	0	1	-	0	0	0	1
Total	2	1	6	0	0	0	9

Discussion

Overall, the results of the current study provide a more comprehensive view of the dolphins' behavior and learning when given access to an interactive system. This re-examination of the data provided further evidence the dolphins learned and understood the contingencies of the keyboard use. Through their self-directed keyboard interactions, in the absence of explicit training, the dolphins spontaneously developed associations between the three temporally paired elements (visual symbols, novel computer-generated whistles, and objects and activities) presented during keyboard sessions. Furthermore, both Pan and Delphi appeared to employ this knowledge to generate desirable outcomes for themselves. When taken into account with the acoustic data that were published in Reiss and McCowan (1993), these findings additionally suggest that the dolphins' behavior, keyboard use, and vocal learning developed in tandem. The dolphins' exhibited behavioral concordance in their use of the visual symbols, productive use of the novel acoustic elements, and behavior were indicative of self-organized learning.

Overall Keyboard Use

Both dolphins displayed a change in keyboard usage over the course of the four data collection periods. Pan, and later Delphi, quickly revealed a considerable preference for fish as a reward and tracked the Fish key when it was accessible. The consistent use of the Fish key in Year 1 FCF, combined with the low numbers of blank key hits, reinforced the conclusion that Pan had begun to understand the contingencies of the keyboard quickly; Delphi's key use followed this pattern as well, although later in the study. This is corroborated by the recorded observation by the researchers of Pan's behavioral response of pressing an actual fish to a blank key in the first session in which the fish symbol was not presented. This behavior was repeated three times in quick succession, and the researchers reported it was obvious to everyone present who had observed this behavior that Pan had been trying to request fish using the keyboard, even though the designated key was not available.

Delphi, too, showed a preference for the Fish key but to a lesser extent than Pan. Interestingly, while Pan had started to eat fish soon after the introduction of the keyboard, Delphi had not yet begun to eat fish during the first year of data collection (Year 1 FCF and FCR). Prior to his first key hit, however, Delphi had been at station and observed Pan using the keyboard for 138 out of 641 key hits; 80.4% of these were instances when Pan hit the Fish key. As previously mentioned, it has been well-documented that dolphins have displayed a propensity for observational learning (Adler & Adler, 1978). Therefore, it is possible that Delphi's use of the Fish key, which held no inherent appetitive value for him, was influenced by Pan's keyboard usage. The apparent impact of Pan's usage continued in Year 1 FCR even after the Fish key was removed: both dolphins displayed a position preference for Position 0 (upper left-hand corner) as well as no key preferences.

After the two-year hiatus with no access to the keyboard, the way that the dolphins used the apparatus was altered drastically. While during the first year (Year 1 FCF and FCR) Pan had utilized the keyboard first and the most regularly, in Year 2 FCR Delphi began using the keyboard first and had the highest number of total key hits between the two dolphins. The first two sessions that Delphi used the keyboard during the second year revealed an unusually large number of hits to blank keys; it is possible that with so much time since the last usage, Delphi might have been re-checking the contingencies. This is additionally supported by the lack of any blank key hits after the latter of these sessions. Delphi then exhibited a key preference for Ball and Ring, while Pan still frequently chose whichever key was located in Position 0. Moving into Year 3 FCR, Pan began to show a slight key preference for Ball, although it was not nearly to the extent of his Fish key usage. Delphi, on the other hand, still preferred Ball but also began to hit for a new item, R Float. First key hits paralleled the preferences found in the overall key hits for Delphi in Year 2 and for both dolphins in Year 3.

Understanding of Contingencies (Acceptance/Rejection of Rewards)

For the first three data collection periods, rewards were accepted more than rejected by both Pan and Delphi. However, during Year 2, there was a considerable drop in the “Accept” response: it is likely that this was due to it being split into the two categories “Accept/Play” and “TNP.” When separating out the instances of responding Accept/Play from cases of TNP, an interesting trend was uncovered for one item in particular: the reward, Ball. In Year 1, the only types of Ball rewards offered to the dolphins were air balls, which floated to the top of the water. In Year 2, the researchers introduced water balls, which were neutral buoyancy, and they randomly alternated between air and water balls as rewards when the Ball key was hit. Delphi began to respond with TNP and Reject when presented with air balls (roughly 60% and 21% of the times he was offered an air ball, respectively). Yet when offered a water ball, he Accept/Played with it much more than he responded with Reject or TNP. The following year of data collection, Delphi did Accept/Play with the air balls but still showed a partiality for the water balls (Accept/Playing with the air balls 53% of the time they were offered while Accept/Playing with the water balls 76% of the time). Pan also responded most frequently with Accept/Play when given a water ball in Year 3, while responding with TNP most often when given an air ball. When asked, one of the original researchers indicated that she had believed that the dolphins had preferred the water balls, although this opinion had been based solely on informal, personal observations. Because the keyboard did not provide the opportunity for the dolphins to use modifiers, they were not able to request specific items such as water balls. It appeared as though the dolphins instead learned to exploit the system to their advantage by refusing certain items and repeatedly pressing the same key, in this case the Ball key, until they received the item that they wanted.

Another noteworthy development was during Year 3: both Pan and Delphi rejected the same two items more than they accepted them. These rewards were Disk, which was one of the two new items that were added to the keyboard, as well as Ring. The other newly added item, R Float, was equally rejected and accepted by the dolphins. A few possible reasons might account for this finding. First, the dolphins could have been testing the contingencies of the new keys; this would explain their responses to the two new items. However, this would not account for why Disk, an item that had appeared on the keyboard before, was extensively rejected. A second explanation could be that the dolphins were simply getting pickier: perhaps, similar to how they used the Ball key, they were rejecting rewards until they received the specific item that they favored. Lastly, it could be that the control over obtaining the model sounds, or the sounds themselves, had been reinforcing to the dolphins. Control, in and of itself, has previously been shown to be reinforcing for other species (Kish, 1955; Kish & Barnes, 1961). Similarly, as evidence clearly indicates that dolphins are vocal learners (Hooper, Reiss, Carter, & McCowan, 2006; McCowan & Reiss, 1995), acoustic elements are particularly salient to this species. Therefore, either the control and/or the acoustic sounds could have been more reinforcing than the objects or activities being received.

Multi-Toy Play

Multi-toy play using items obtained via the keyboard was initially seen in Year 1 FCR and continued throughout the course of the study. For the two years where data about specific play bouts were recorded (Year 1 FCR and Year 2 FCR), an inclination toward one combination in particular emerged: both dolphins overwhelmingly preferred Ring-Ball double-toy play over any other combination. When consulting the acoustic findings from Reiss and McCowan (1993), it was revealed that both the Ring whistle and Ball whistle, individually, were the most mimicked of all the item-specific facsimiles. Then, in Year 2 FCR, the dolphins were recorded for the first time spontaneously producing their created “Ring-Ball” combination whistle. Regrettably, limitations in the technology did not allow for the localization of sound in order to determine which of the dolphins was producing this combination whistle. It should be noted that while Pan exhibited double-toy play in Year 2 about the same amount as he had in the first year, Delphi had a three-fold increase in double-toy play. Additionally, the Ball and Ring keys were hit in almost equal amounts by Delphi as well as by Pan in Year 2, while also being the two most requested items in that period. Delphi’s upswing in pressing the corresponding keys for, and playing with, Ring and Ball rewards appeared to correspond with the increased rate of production of the “Ring-Ball” whistle, as reported in Reiss and McCowan (1993). These points taken together grant further support for the concept that the dolphins showed co-development of their acoustic and multi-toy play behaviors, as well as their keyboard usage.

Interceptions

Both Pan and Delphi were found to have intercepted rewards, with Delphi performing the first instance. As discussed earlier, Delphi was not yet eating fish, yet many of his key hits and all of his interceptions in Year 1 FCF were for fish: this indicated that fish held some reinforcing property for him that was not appetitive. Delphi had seen his mother, as well as Pan’s mother, eating fish; also, directly prior to this first interception, Pan had been playing with the fish he had received using the keyboard while Delphi was at station. Thus, one potential explanation is that the social influences of the other dolphins he regularly interacted with led to Delphi placing a high value on fish.

Year 1 FCF was the only time period where Delphi had a higher number of interceptions than Pan. From Year 1 FCR onward, Pan was witnessed intercepting the most rewards out of the two dolphins. In Year 2 FCR, the rewards Pan overwhelmingly intercepted from Delphi were Ball followed by Ring. As stated earlier, Ball and Ring were Pan's preferred combination for double-toy play. Thus, Pan's high rates of interception in Year 2 FCR, coupled with the fact that Pan did not use the keyboard until the final sessions this period, implied that he might have been "using" Delphi to obtain rewards from the keyboard without having to operate the keyboard himself. Pan was the oldest of the two dolphins and Pan's mother, Terry, was the dominant female within the group; Pan himself began using the keyboard first and intercepted the most rewards overall. Taken together, the evidence indicates that Pan might have been dominant over Delphi during at least part of the study. Since male dolphins have been found to have flexible dominance patterns (Samuels & Gifford, 1997), Delphi intercepting rewards first in Year 1 FCF as well as the decrease in interceptions by both dolphins in Year 3 could have been due to a shifting of dominance between the two young males. Unfortunately, there is no further data regarding the calves' dominance patterns at the time to be able to say for certain if this was the case.

Importance of Findings

The present study in conjunction with the findings from Reiss and McCowan (1993) provide intriguing data on the patterns of behavior and learning that occurred when captive dolphins were given more choice and control through the provision of an underwater interactive system. As many zoos and aquariums have embraced more science-based initiatives, the welfare of the animals in their care has become of utmost concern (Hill & Broom, 2009). From the 1970s onward, an increased interest in this topic has resulted in numerous studies being developed that focused on improving captive animal welfare. Moreover, these studies gave us a window into the cognitive abilities of various species and the importance of providing them with choice and control. The study by Reiss and McCowan (1993) encapsulated all of these points. Their results coupled with those of the present study provided insights into the process of dolphin vocal learning, spontaneous vocal learning and imitation, and their ability for spontaneous association learning. The provisioning of the interactive keyboard system and the documentation of the dolphins' acoustic and behavioral interactions over time revealed that they showed the emergence of self-organized learning. Additionally, the present study provided an opportunity to examine how both the mother-offspring relationship as well as the flexible dominance hierarchy displayed by male bottlenose dolphins might be involved in vocal and self-organized learning. Although more work is needed on this topic, the evidence thus far appears to support the importance of both types of social relationships in learning.

Technology has rapidly progressed in recent decades and as a consequence, interactive systems can provide a means of increasing an animal's perceived control while in captivity. Significant leaps have been made using technology with captive species. In fact, zoos have begun to incorporate such technologies into their enclosures to give the animals more control: these have included enclosure modifications at the Los Angeles Zoo, Zoo Atlanta, and the Miami Zoo that allow the apes to spray water at visitors (Clay, Perdue, Gaalema, Dolins, & Bloomsmith, 2011) and even a mobile robot with a camera that can be controlled by a primate to explore areas outside of its enclosure (Dolins et al., 2017). However, there is still much to learn about creating interactive systems that provide captive animals with measures of control over their environment that address the species' sensory and cognitive abilities. For example, the design features of the keyboard system of Reiss and McCowan (1993) incorporated visual and auditory elements that were based on the dolphins' sensory capabilities and which could be used productively by the dolphins. The present re-examination of the seminal study of Reiss and

McCowan (1993) reveals the efficacy of how the provision of choice and control can shape learning and behavior over time.

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