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NEWS AND PERSPECTIVES

# Behavioral recovery from tetraparesis in a captive chimpanzee

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**Abstract** An adult male chimpanzee living in a captive social group at the Primate Research Institute of Kyoto University developed acute tetraparesis. He was paralyzed and received intensive care and veterinary treatment as previously reported in Miyabe-Nishiwaki et al. (J Med Primatol 39:336–346, 2010). The behavioral recovery of the chimpanzee was longitudinally monitored using an index of upright posture between 0 and 41 months after the onset of tetraparesis. Four phases were identified during the course of behavioral recovery. During Phase 0 (0–13 months), the chimpanzee remained lying on his back during the absence of human caretakers. An increase in upright posture occurred in Phase I (14–17 months), then remained at a stable level of around 50–70 % in Phase II (18–29 months). During Phases I and II, the subject's small treatment cage represented a spatial limitation. Thus, behavioral recovery was mainly mediated by arm muscle strengthening caused by raising the body trunk with the aid of materials attached to the cage walls as environmental enrichment. When the chimpanzee was moved to a larger rehabilitation room in Phase III (30–41 months), the percentage of upright posture constantly exceeded 80 %, except in the 40th month when he injured his ankle and was inactive for several days. The enlargement of the living space had a positive effect on behavioral recovery by increasing the types of locomotion exhibited by the subject, including the use of legs during walking. Rehabilitation works were applied in face-to-face situations which enabled the use of rehabilitation methods used in humans. The process of behavioral recovery reported in this study provides a basic data set for planning future rehabilitation programs and for comparisons with further cases of physical disability in non-human primates.

**Keywords** Chimpanzee · Tetraparesis · Disability · Rehabilitation · Environmental enrichment

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## Introduction

Monitoring of animal behavior provides a useful measure for assessing the health and psychological condition of an individual. Behavioral measurements can also be used to assess welfare states and the effects of environmental enrichment on non-human primates (Hosey et al. 2009; Yamanashi and Hayashi 2011; Young 2003). Such research efforts are becoming increasingly widespread in studies of captive primates; however, the majority of these focus on behaviors performed by healthy individuals, while neglecting those with disabilities. Moreover, only a few scientific reports have been published on the care and behavior of disabled primates in captivity (Alford and Satterfield 1995), and these cases were handled independently by each facility without comparative data or knowledge. Here, we report on the longitudinal change in behavior of a captive chimpanzee recovering from tetraparesis.

The Primate Research Institute (PRI) of Kyoto University (Inuyama City, Aichi, Japan) is home to 14 chimpanzees living in social groups in enriched enclosures (Matsuzawa 2006). On the morning of 26th September


**Fig. 1** **a** Still image of the chimpanzee Reo in the enriched treatment cage. **b** Still image taken from video footage recorded in the small treatment cage. Reo is in the *middle* of the cage, sitting on the bed with the support of ropes. **c** Still image taken from video footage recorded in the rehabilitation room. Reo is sitting on a platform at the *left-hand side* of the image, holding on to a rope hanging from the ceiling. A bed is positioned at the *right-hand side* of the room

2006, one of the adult male chimpanzees, named Reo (24 years old), was found lying down on the ground in an outdoor enclosure. He appeared conscious but unable to move his body below the neck. Reo was isolated from other group members and anesthetized for physical examination and diagnostic testing. His condition resembled acute transverse myelitis (ATM) in humans (Miyabe-Nishiwaki et al. 2010).

Miyabe-Nishiwaki et al. (2010) reported the first 2 years of the chimpanzee's recovery process from a veterinary perspective. Reo was kept in a small treatment cage and received intensive care administered by veterinarians, keepers, researchers, and students. His body weight was 57 kg at the onset of the disease but rapidly decreased to 35 kg, well below the normal range for an adult male chimpanzee (Hamada et al. 1996). Reo developed pressure ulcers in many parts of his body. The staff continued care and enrichment efforts by installing a customized bed in Reo's treatment cage, giving him toys and objects, and interacting with him (Fig. 1a). Reo started to move his arms and became able to raise his body by himself after 10 months from the onset of tetraparesis. Pressure ulcers gradually diminished and had completely healed by around 23 months after the onset. Reo was relocated to a larger rehabilitation room at 30 months from the onset.

Chimpanzees can live more than 50 years (Thompson et al. 2007), and thus we were faced with the prospect of Reo living with his disability for several more decades. Chimpanzees are group-living primates, and long-term isolation can cause deterioration in both the physical and the psychological condition of an individual. Thus, the final goal of rehabilitation is integration into a suitable social group. In pursuit of this ultimate goal, we need to monitor and evaluate behavioral recovery to devise appropriate rehabilitation protocols during daily activities.

The inflammation in Reo's spinal cord and his recovery from pressure ulcers were already reported and evaluated in Miyabe-Nishiwaki et al. (2010). The present report conducts behavioral analysis in order to assess the longitudinal process of recovery in our chimpanzee subject. We had been video recording Reo's behavior from the onset of his tetraparesis and used these cumulative records for our analysis. The videos were taken from outside of the chimpanzee's cage, hence his subtle movements and facial expressions were not always detectable. However, the videos were sufficient to judge whole body posture.

We used body posture as a behavioral indicator of the chimpanzee's recovery. The longitudinal change in the ratio of lying versus upright posture was evaluated through analysis of our video records. We report the process of behavioral recovery and the effect of the home cage environment on this recovery. We also report our rehabilitation efforts conducted in a face-to-face situation, which were comparable with human rehabilitation programs. The data provided in this report can be used as a basic behavioral data set for future assessment and planning of rehabilitation schemes for chimpanzees. Moreover, it may enable future comparisons with similar cases in disabled primates requiring long-term rehabilitation and special care.

## Methods

### Subject

Our subject was an adult male chimpanzee, named Reo. Reo was born on 18th May 1982, as a result of artificial insemination between Gon (the father) and Reiko (the mother; Matsubayashi et al. 1985), and was 24 years old at the onset of tetraparesis. Reo was raised by his mother until around 1 year of age and was thereafter housed with two cage mates before he was integrated again with the mother and other unrelated chimpanzees. Reo participated in various cognitive tests at PRI, including face-to-face tasks and computer-controlled tasks (Fushimi 1994; Takeshita 2001; Tanaka 1995; Tomonaga et al. 1991). He had been the alpha male in a group of five chimpanzees before the onset of tetraparesis.

### Keeping environment

Reo was in a sunroom (around 250 $m^2$) at the time of the onset of tetraparesis, which occurred in the morning of 26th September 2006. From the day of onset, he was kept alone in a small treatment cage (around 1 $m^2$; Fig. 1b). He was moved to a larger rehabilitation room (around 10 $m^2$; Fig. 1c) on 7th April 2009. Bed, bars, and ropes were provided in the treatment cage and were adjusted and refined according to Reo's condition (Kaneko and Watanabe 2009). Ropes and an apparatus for cognitive tasks were installed in the larger rehabilitation room to facilitate and encourage his movement (Tomonaga 2010). A video camera was set up just outside the cage to record the chimpanzee's behavior 24 h daily.

### Video analysis

We analyzed videos taken between 0 and 41 months after the onset of tetraparesis. The behavioral data was collected for the hour between 1300 and 1400 h each day, which excluded any human presence, thereby avoiding interference from human care-taking activity. Data collection was carried out using a 1-min time-sampling method. Data were collected from the first 10 days of each month, excepting days when Reo received veterinary treatment that included anesthesia. The anesthesia was conducted once or twice per week until 16 months, then once a month until 21 months after the onset of tetraparesis for medication, blood sampling, treating the pressure ulcers, and cleaning/improving the bed (Miyabe-Nishiwaki et al. 2010).

### Behavioral categories

Two basic behavioral categories were chosen to track long-term changes in the chimpanzee's postural ability: lying posture and upright posture. The former was used to describe cases when the subject's body trunk remained horizontal, with his back touching the bed. The latter was used when the subject's body trunk was vertical, and his back was not touching the bed. Upright posture was further broken down into "sitting with/without support" and "moving by using hands/feet".

## Results

### Overall results

Figure 2 shows the percentage of samples during which Reo assumed upright posture over the course of the present study period, 0–41 months after the onset of tetraparesis. During the first 13 months, the ratio of upright posture was always zero during the time of day analyzed (1300–1400 h). In other words, Reo remained lying on his back during the absence of human caretakers although he first succeeded to temporarily sit up during interaction with humans at 10 months after the onset. The ratio of upright posture increased to 3.0 and 9.2 % in the 14th and 15th months after the onset, respectively. The 16th month saw an even more drastic increase, to more than 40 %. In the months that followed, the ratio of upright posture remained at a roughly stable level (55–75 %). Thus, Reo's postural abilities recovered gradually, even in the confines of the smaller treatment cage. The ratio of upright posture increased to more than 85 % after he was relocated to the larger rehabilitation room 30 months after the onset.

We identified four periods of recovery through our analysis of monthly average ratios of upright posture. Phase 0 covered the period between 0 and 13 months, Phase I was 14–17 months, Phase II was 18–29 months, and Phase III was 30–41 months after the onset of the tetraparesis. During Phases 0, I, and II, Reo was kept in the smaller treatment cage, while the beginning of Phase III coincides with his being moved to the larger rehabilitation room.

### Phases 0 and I

During Phase 0 (0–13 months), upright posture was not recorded during the absence of humans. During Phase I (14–17 months), the average ratio of upright posture was less than 50 % and the maximum ratio was no more than 75 % per month. These periods overlap with the data used in Miyabe-Nishiwaki et al. (2010) on the process of pressure-ulcer healing and body-weight change. Miyabe-Nishiwaki et al. (2010) reported that pressure ulcers were ameliorated around 450–500 days after the onset of tetraparesis. This period corresponded to months 15–16, which our current analysis confirms was characterized by an increase in the ratio of upright posture. Reo's body weight decreased from 57 to 35 kg in the first 2 months but gradually increased again in the following period (Fig. 2). The dominant behavioral pattern during Phase I was sporadic raising of the body trunk, with relatively short sitting durations.

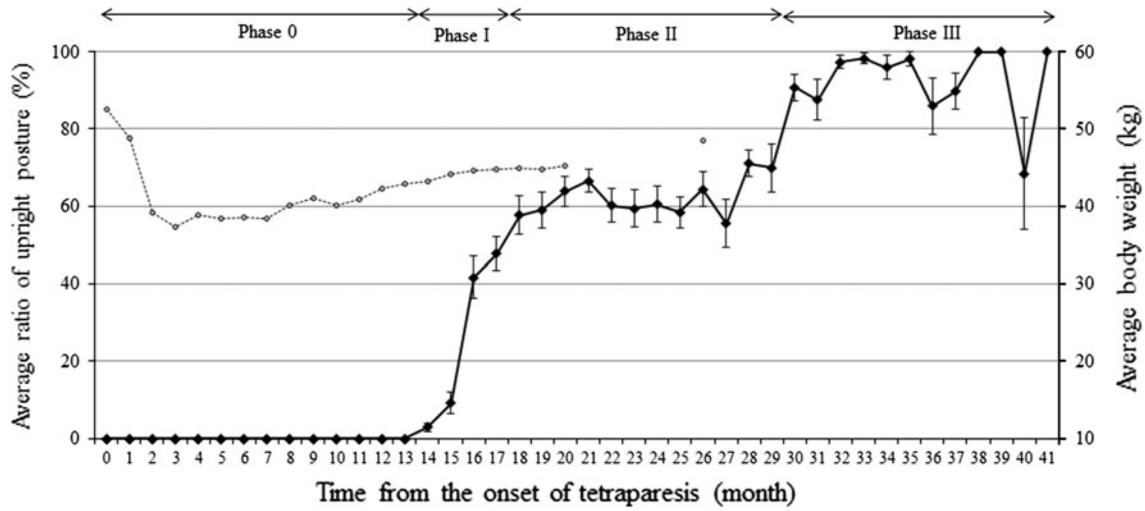


**Fig. 2** *Solid line* shows the percentage of upright posture from 0 to 41 months after the onset of tetraparesis. *Error bars* show standard deviation. *Dotted line* shows the body weight of Reo

Phases II and III

During Phase II (18–29 months), the average ratio of upright posture was 55–75 % and the maximum ratio was 75–95 % per month. During Phase III (30–41 months), the average ratio of upright posture was more than 85 % (except the 40th month when Reo suffered an injury to his ankle) and the maximum ratio was 100 % each month. A binomial test comparing Phases II and III showed a significant increase of upright posture in Phase III ($\chi^2 = 1767.057$, $p < 0.001$; Fig. 3). The dominant behavioral pattern during Phase II was sitting with the support of materials in the cage, and Reo also sometimes moved to the other side of the cage, away from the bed/lying area. The behavioral repertoire observed during Phase III showed more variation than the previous two phases and included walking with/without support on the floor and brachiation using ropes hanging from the ceiling. These types of locomotion indicated the recovery of muscles in both the arms and the legs and were enabled by the enlargement of Reo's living space.

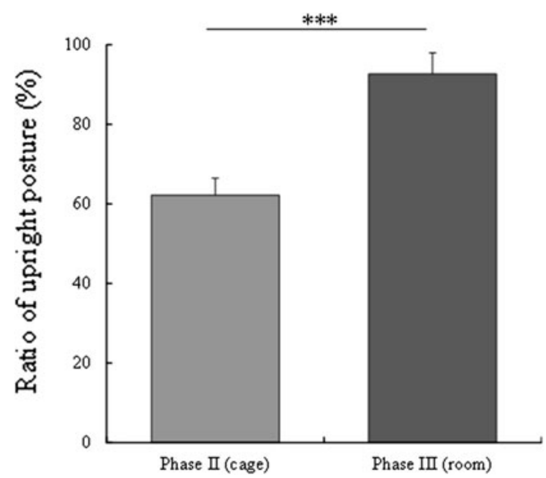


**Fig. 3** Average percentage of upright posture during Phases II and III. *Error bars* show standard deviation

Extension rehabilitation in face-to-face situations

PRI has a long history of conducting face-to-face tests with chimpanzees, including adult subjects (Hayashi and Takeshita 2009; Kano and Tomonaga 2013). Humans who have long-term experience interacting with chimpanzees can enter the same room as the subjects and conduct cognitive tasks, health checks, or handlings. In the case of Reo, one keeper (S.W.) and one veterinarian (A.K.) were able to have direct contact with Reo even in the small treatment cage during Phases 0 to II. They helped reposition Reo on his bed and encouraged him to raise his body using his arms in Phase 0. This encouragement by humans promoted the active use of arms, indicated by the early appearance of upright posture under the condition of human presence already in 10 month during phase 0 in this study, before spontaneous raising in the absence of humans. The two humans directly interacted and played with Reo in the treatment cage continuously during Phases I and II to encourage him to move his body, especially the movable arms in Phase I and the whole body in Phase II, as a method of exercise in the limited space. In the larger room during Phase III, the two humans conducted rehabilitation in a face-to-face situation (Fig. 4, Online Resource 1). They encouraged Reo to walk on his legs with and without support materials, such as ropes and wooden benches at floor level. They temporally placed a wedge-shaped sole customized for Reo's feet to extend his contractured toes

**Fig. 4** Still image of face-to-face interaction between Reo and human caretakers during rehabilitation

while walking. The two humans took complementary roles in interacting with Reo during the rehabilitation: while the keeper was playing with or grooming Reo, the veterinarian extended the joints in his arms and legs. This dual approach helped divert Reo's attention, making him more tolerant towards the pain resulting from the manipulation of his joints. Since the two humans had established strong affectionate bonds with Reo, he readily accepted the interactions, and these could proceed in a playful and relaxed atmosphere. Although no quantitative analysis has been performed for these situations, we expect this rehabilitation method had a positive effect on the behavioral recovery, as indicated by the early emergence of upright posture in the presence of humans.

## Discussion

The present study is the first report on the long-term care and rehabilitation of a disabled chimpanzee. Our data clearly show the exponential functional increase of upright posture along with the recovery of body movement after the onset of tetraparesis. Future study is needed to identify a set of valid indices for rehabilitation evaluation in non-human primates. In human physical therapy, there is a basic flow of rehabilitation that is common to all kinds of disability (Yanagisawa, 2011): (1) range of motion (ROM) and muscle strengthening exercises, (2) basic action exercises (repositioning, raising, sitting endurance, standing up, transferring, walking), (3) activities of daily living (ADL) training (eating, changing clothes, self care, going to the toilet, moving, bathing), (4) instrumental activities of daily living (IADL) training (cooking, washing, shopping, cleaning, performing hobbies, outdoor moving), (5) job/school support, community integration, social participation. In the present case, from the above list, rehabilitation based on ROM and muscle strengthening exercises may have worked to increase Reo's body weight in Phase 0. During Phase I, his body weight reached a plateau, suggesting that his muscle had recovered to some extent and the second stage (raising, sitting endurance) were achieved. Muscle strengthening, raising, and sitting endurance may be facilitated through environmental enrichment in the treatment cage. Miyabe-Nishiwaki et al. (2008) reported that Reo used ropes and bars in the treatment cage for chin-ups and by 10 months after the onset succeeded to temporarily sit up by himself holding a bar. Repeating this behavior led him to establish sitting endurance. The process of recovery in the chimpanzee was comparable to that in human rehabilitation, thus we may apply the same evaluation standards and use these to devise new rehabilitation programs in non-human primates.

During Phase II, Reo used ropes for moving inside the treatment cage (Hayashi and Sakuraba 2009). However, the small cage provided many spatial limitations, and it was difficult for Reo to develop a variety of locomotor behaviors and to assume a constant upright posture. As a result, recovery during Phases I and II was characterized by the recovery of arm strength. The spatial limitation was eliminated in Phase III with transfer to the larger rehabilitation cage. This change enabled the chimpanzee to develop new locomotor behaviors such as walking and brachiation and led to the recovery of a more naturalistic repertoire of locomotion. The increase in the percentage of upright posture in Phase III seemed to be linked with the recovery of locomotor capacity in the whole body, including walking and brachiation as additional locomotor behaviors. The enlargement of living space and the provision of enrichment materials that support the chimpanzee's locomotion thus promise to enhance recovery after paralytic disease.

Reo suffered an accident involving an ankle injury at 40 months after the onset. He remained in bed for 2–3 days and the percentage of upright posture dropped below 70 % for the month. The change in the living environment enabled the emergence of a variety of behaviors. However, at the same time, we need to closely monitor the subject's behavior to prevent injuries caused by excessive locomotion and also to evaluate the effects of environmental enrichment. If the increase in lying posture is a reliable index of injury in chimpanzees, we can use it as a clear indicator in future monitoring.

From the onset of disease, Reo was kept separated from other members of the chimpanzee groups at PRI. Reo sometimes vocalized in response to the vocalizations of other chimpanzees in outdoor enclosures. On several occasions, we called in a female chimpanzee from the outside enclosure to interact with Reo through the mesh barrier of the rehabilitation room. These trials were, however, soon abandoned, since the two individuals failed to consistently interact non-aggressively with each other through the barrier. We also judged it unsafe to allow the two chimpanzees to interact directly, without any physical barrier. Therefore, we recently introduced a real-time monitor that enabled Reo to see and interact with the mother chimpanzee, Reiko (Adachi and Tomonaga, personal communication). Human staff continued to try to compensate for Reo's social needs by direct and indirect contact with him. Interestingly, prior to the onset of disease, when Reo lived in a social group of chimpanzees, he was rarely friendly towards humans. When he started to receive intensive care by human caretakers, he began to show affiliative behavior towards some of the human staff. At present, he customarily emits greeting grunts and spontaneously plays with human staff. Nonetheless, our longer term perspective is to attempt to integrate Reo into a social group of chimpanzees by continuing rehabilitation efforts that will allow him to recover locomotor abilities closer to the normal chimpanzee range. Another option considered is to move Reo's living space next to an outdoor enclosure where other chimpanzees live.

Reo is receiving one session of extension rehabilitation per week (Kaneko and Watanabe 2009) and two sessions of computer-controlled rehabilitation per day (Sakuraba 2013; Tomonaga 2010). PRI staff has been making rehabilitation efforts during their individual interactions with Reo. Human presence and encouragement had a positive effect on Reo's behavioral recovery. Video records used in the present study were not sufficient to evaluate details of the behavior; thus, we need direct observation to finely monitor the recovery process and to evaluate the rehabilitation efforts using fine-scale quantitative data. We also need behavioral data from normal chimpanzees to compare and highlight problems in Reo's behavior and to better plan our program of rehabilitation. It is also possible to apply methodology and schedule of rehabilitation from human physical therapy in face-to-face situations. Our study may be a useful starting point for establishing the new discipline of "chimpanzee rehabilitation" or "comparative rehabilitation".

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