Journal of King Saud University – Science (2015) **27**, 260–270

King Saud University
**Journal of King Saud University – Science**
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ORIGINAL ARTICLE

# Timing of changes from a primitive reflex to a voluntary behavior in infancy as a potential predictor of socio-psychological and physical development during juvenile stages among common marmosets

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Received 1 October 2014; accepted 17 March 2015
Available online 21 March 2015

**KEYWORDS**

Developmental milestones;
Motivation;
Gravity environment;
Multivariate analysis;
Body weight;
Head surface temperature

**Abstract** With regard to socio-psychology, the complexity of a human's neuronal function develops from initial primitive function to multimodal networking gradually through interaction between innate biological mechanisms and the surrounding environment. To study these developmental systems, we attempted to find a comparative-behavioral model among non-human primate species, common marmoset (*Callithrix jacchus*). In this research, we explored the correlation between the timing of change from involuntary- to voluntary-like movement in early stage and later the socio-emotional behavior, comparatively with the probable psychological

*Abbreviations*: IAT, Infant Antigravity Task; SBT, social behavior test; bGlc, blood glucose concentration; $T_{head}$, head surface temperature; Theta 45, face preference to reference in SBT

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Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jksus.2015.03.005

development disabilities defined by our social behavior test (SBT). Using the 'Infant Antigravity Task (IAT)' and multivariate analysis, we quantitatively observed the neurological development from simple to complex behavior through interaction between motor and gravity environment. At the same time, we recorded the physiological and psychological development of two marmoset siblings (a male and a female) from their neonate stages to adult stages with their parents. In their lives, the male marmoset spontaneously showed his developmental delay in terms of body weight, blood glucose and socio-emotional difficulties under their own parental care. Based from the SBT results, the male demonstrated less social interaction with other family members compared to his sibling in the juvenile stage. Between these siblings, we looked for any predictable information in the earlier stage for future developmental issues particularly focusing on their behavioral expression during IAT from the 10th postnatal day until the 36th day.

Consequently, we found that both subjects expressed climbing-up behavior in the initial early period, but only the female who developed typically later, switched to jumping-down behavior with pre-facing to 'down' direction. Meanwhile, the male who would have developmental delay later, clearly did not show the switching pattern. The results suggest that the switch timing from involuntary to voluntary movement may be a possible predictor of juvenile and adolescent physiological and psychological retardation. The results also suggest that the primate model allows more methods to be developed for early detection of developmental disabilities that could be utilized in humans to pave the way for interventions and possible psychological or psychiatric treatment.



## 1. Introduction

The idea that earlier treatment during the development is the most powerful, has been agreed upon in the fields of education and medicine. Considering the development of our neuropsychological higher-order function, the biological basis may already start forming from the embryonic stage and it develops in infant, juvenile, adolescent and even adult and elderly stages step by step. These accumulated modules hierarchically integrated to form complex neurobiological information networks. In the earliest stage, humans express multiple kinds of primitive reflexes (Schott and Rossor, 2003; Blasco, 1994) as simpler central nervous systems of automatic regulation with sensory input from environment and motor output and interaction with environment. The primitive reflexes, including Moro reflex, grasping and rooting mostly appear transiently and disappear in the later developmental stages. Instead, more complex motor control behaviors appear, such as, 'head control', 'rolling over', 'sitting', 'standing' and 'walking' which are known as developmental milestones requiring higher-order nervous systems including voluntary function. In the series of motor developmental expression shifting, it has been reported possibility to predict the sign of psychological disabilities such as Asperger's syndromes and autistic spectrum disorders by visualizing some behavioral characteristics and follow-up on the development (Teitelbaum et al., 2004; Jones and Klin, 2013). For innovation on non-established psychiatric treatment, we studied the neuronal development mechanisms from primitive to complex. The developmental process is thought as an interaction between biological and environmental mechanisms. We reported a possibility that the neonatal infant brain development affected by preterm metabolic conditions may predict the latter neuronal development of voluntary behavioral control (Koshiba et al., 2014) that is also relevant to the psychological development.

New world monkeys, common marmosets (*Callithrix jacchus*) are monogamous primates and make a small family for breeding. It is known that all family members cooperate with one another for breeding offsprings and we can often see the father taking care of the siblings except for feeding time during which the mother gives the offspring her own milk (Zahed et al., 2008). Their superior psychological capacity for socially cooperative communication (Flack, 2013) and altruistic behavior (Burkart et al., 2007) has led to the development of primate neurobiological systems in genetic and environmental interaction (Jokela et al., 2007) for studies of neurobiological psychiatry as an essential pre-clinical model (Okano et al., 2012) .

In this study, we firstly explain our evaluation of hypothetical diagnostic methods to quantitatively visualize the development of common marmosets focusing on their selection of antigravity relevant behavioral patterns that can be confirmed through the behaviors that appear or disappear over ages. A neonatal marmoset infant, after birth, grasps its parent's body and clings to it continually to maintain the appropriate body temperature and to be protected from outside risks. The neonatal infants can reach the mother's breast with its own control and parental supports under gravity loading. Their climbing ability may be considered as their primal capacity for grasping like humans do, by using the palmar and planter reflexes. A motor control and an activity test for the motor development in neonatal infants among common marmosets had been previously conducted with instrument and subjects' climbing behaviors (Tardif et al., 2002). We furthermore challenged to discriminate the process from involuntary primitive to voluntary advanced function in their behaviors under a gravity environment. To seek any predictors in the behaviors, we selected the subjects who have been discriminated from their developmental troubles with our original quantitative analytic systems (Koshiba et al., 2011, 2013a,b,c,d,e; 2014, 2015; Senoo et al., 2011). The subjects of the study are two siblings raised by their own parents. In the results, we will firstly present the developmental history of the typical female and a male with spontaneous delay and describe our diagnosis, intervention and treatment results. Then, we will introduce our