Replacement of Neanderthals by Modern Humans Series

Takeru Akazawa
Naomichi Ogihara
Hiroki C. Tanabe
Hideaki Terashima *Editors*

Dynamics of Learning in Neanderthals and Modern Humans

Volume 2

Cognitive and Physical Perspectives

Springer

Replacement of Neanderthals by Modern Humans Series

Edited by

Takeru Akazawa
Research Institute, Kochi University of Technology
Kochi 782-8502, Japan
akazawa.takeru@kochi-tech.ac.jp

Ofer Bar-Yosef
Department of Anthropology, Harvard University
Cambridge, Massachusetts 02138, USA
obaryos@fas.harvard.edu

The planned series of volumes will report the results of a major research project entitled "Replacement of Neanderthals by Modern Humans: Testing Evolutionary Models of Learning", offering new perspectives on the process of replacement and on interactions between Neanderthals and modern humans and hence on the origins of prehistoric modern cultures. The projected volumes will present the diverse achievements of research activities, originally designed to implement the project's strategy, in the fields of archaeology, paleoanthropology, cultural anthropology, population biology, earth sciences, developmental psychology, biomechanics, and neuroscience. Comprehensive research models will be used to integrate the discipline-specific research outcomes from those various perspectives. The series, aimed mainly at providing a set of multidisciplinary perspectives united under the overarching concept of learning strategies, will include monographs and edited collections of papers focusing on specific problems related to the goals of the project, employing a variety of approaches to the analysis of the newly acquired data sets.

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akazawa.takeru@kochi-tech.ac.jp

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Editors

Dynamics of Learning in Neanderthals and Modern Humans Volume 2

Cognitive and Physical Perspectives

Proceedings of the international conference on "*Replacement of Neanderthals by Modern Humans: Testing Evolutionary Models of Learning*", organized by Takeru Akazawa, Shunichi Amari, Kenichi Aoki, Ofer Bar-Yosef, Ralph L. Holloway, Shiro Ishii, Tasuku Kimura, Yoshihiro Nishiaki, Naomichi Ogihara, Hiroki C. Tanabe, Hideaki Terashima, and Minoru Yoneda, which took place in Tokyo, November 18–24, 2012, Volume 2.

Edited by

Takeru Akazawa
Kochi University of Technology, Kochi, Japan

Naomichi Ogihara
Keio University, Yokohama, Japan

Hiroki C. Tanabe
Nagoya University, Nagoya, Japan

Hideaki Terashima
Kobe Gakuin University, Kobe, Japan

Springer

Editors
Takeru Akazawa
Research Institute
Kochi University of Technology
Kochi, Japan

Naomichi Ogihara
Department of Mechanical Engineering
Faculty of Science and Technology
Keio University, Yokohama, Japan

Hiroki C. Tanabe
Graduate School of Environmental Studies
Nagoya University
Nagoya, Japan

Hideaki Terashima
Department of Human Psychology
Faculty of Humanities and Sciences
Kobe Gakuin University
Kobe, Japan

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Preface

Knowledge about the pathways of human evolution has expanded dramatically as a result of advances in genetic, paleontological, and archaeological studies in the twentieth century. One excellent example is the resolution of the issue of the origin of modern humans, long a source of great controversy; namely, the idea that modern *Homo sapiens* are direct related genealogically to Eurasian archaic humans was rejected, and the “Out of Africa” theory, which is now the accepted evolutionary model, was vindicated. However, this new theory only gave rise to a flurry of new questions, one of which centers on the drama of the replacement of the archaic Neanderthals by modern *Homo sapiens*.

Modern humans appeared in Africa about 200,000 years ago; as they subsequently spread across Eurasia, they encountered the indigenous Neanderthals. The two populations coexisted until 30,000 years ago or perhaps even later, but the Neanderthals eventually went extinct. What governed the fates of the two groups? A number of current hypotheses have been proposed to explore the possible mechanics of the replacement of Neanderthals by modern humans, and there has been extensive debate as to whether or not the presence of the modern humans accelerated the extinction of the Neanderthals. This question is being hotly debated among archaeologists, anthropologists, and geneticists around the world.

We are actively engaged in a 5-year (2010–2014) major research project entitled “Replacement of Neanderthals by Modern Humans: Testing Evolutionary Models of Learning” (RNMH). In launching RNMH we have adopted a large scale innovative assault on this research question. The RNMH project implements a pioneering framework structured around the contrast between the success of modern human societies in solving strategic survival problems, and the failure of Neanderthal societies to do so. In that context, we attribute the contrasting fates of the two societies to a difference in learning abilities between the two populations. This is the basis of our working hypothesis (“learning hypothesis”).

The specific goal of this project is to verify the learning hypothesis within an interdisciplinary research framework incorporating new perspectives and methods in the fields of archaeology, paleoanthropology, cultural anthropology, population biology, earth sciences, developmental psychology, biomechanics, and neuroscience. The two present volumes are the proceedings of the first international RNMH conference held in Tokyo in November 2012. Some results have already been published separately in various scholarly journals, but these two volumes constitute the first full attempt to disseminate the findings of our RNMH project to the international research communities. A major purpose in doing so at this halfway point of our project is to solicit scholarly evaluation of these findings.

The 43 submitted manuscripts have been classified into seven sections based on content, and then divided into two groups to be published as two volumes in the Replacement of Neanderthals by Modern Humans series. The first volume is devoted to discussion of cultural perspectives, the second to cognitive and physical perspectives. We hope that these two volumes may contribute significant new insights on the process of replacement and on interactions between Neanderthals and modern humans, and hence on the origins of prehistoric modern cultures.

The editors of this volume are greatly indebted to all our colleagues who supported the publication with their reviews and comments: Juko Ando (Keio University), Emiliano Bruner

(Centro National de Investigación Sobre la Evolución Humana), Nicole Creanza (Stanford University), Laurel Fogarty (Stanford University), Kaoru Imamura (Nagoya Gakuin University), Hiroaki Kawamichi (National Institute for Physiological Sciences), Ryosuke Kimura (University of the Ryukyus), Tasuku Kimura (University of Tokyo), Yasushi Kobayashi (National Defense Medical College), Takanori Kochiyama (Kyoto University), Osamu Kondo (University of Tokyo), Tadashi Koyama (Kobe Gakuin University), Naoko Matsumoto (Okayama University), Alex Mesoudi (Durham University), Takashi Michikawa (University of Tokyo), Naoki Miura (Tohoku Institute of Technology), Masaaki Mochimaru (National Institute of Advanced Industrial Science and Technology), Masaki Moriguchi (Chuo University), Yoshihiro Nishiaki (University of Tokyo), Ryutaro Ohtsuka (Japan Wildlife Research Center), Hiroki Oota (Kitazato University), Herman Pontzer (Hunter College), Makoto Shimada (Fujita Health University), Dietrich Stout (Emory University), Nobuyuki Takahashi (Hokkaido University), Kyoko Yamaguchi (University of the Ryukyus), Eiko Yamagami (Kobe Gakuin University), Taro Yamauchi (Hokkaido University), Kazufumi Yoshihara (Kyushu University). These colleagues read the manuscripts and made critical but constructive comments on the early drafts; this valuable input greatly improved the quality of the volumes. Many thanks to all of them.

We are pleased to acknowledge the Japanese Ministry of Education, Culture, Science, and Technology for their interest in our project and for their financial support, which has made possible our RNMH Project, the conference, and the preparation of this volume.

We would like to thank Ken Kimlicka and Taeko Sato of Springer Japan for heir most valuable guidance and support, and for their tireless encouragement during the preparation of this volume.

May 2013

Takeru Akazawa
Naomichi Ogihara
Hiroki C. Tanabe
Hideaki Terashima

Contents

Contributors

Takeru Akazawa Research Institute, Kochi University of Technology, Kami-shi, Kochi, Japan

Hideki Amano Department of Mechanical Engineering, Faculty of Science and Technology, Keio University, Yokohama, Kanagawa, Japan

Juko Ando Department of Humanities and Social Sciences, Faculty of Letters, Keio University, Tokyo, Japan

Emiliano Bruner Centro Nacional de Investigación sobre la Evolución Humana, Burgos, Spain

Izumi Hagino Laboratory of Human Ecology, Graduate School of Health Sciences, Hokkaido University, Sapporo, Hokkaido, Japan

Yoshinori Haizuka Department of Anatomy, Kyorin University School of Medicine, Tokyo, Japan

Ayaka Hatano Graduate School of Letters, Hokkaido University, Sapporo, Hokkaido, Japan

Naoki Hirai Department of Integrative Physiology, Kyorin University School of Medicine, Tokyo, Japan

Hiroyuki Hishida Research Center for Advanced Science and Technology, University of Tokyo, Tokyo, Japan

Yukinobu Hoshino Engineering Course of Graduate School, Kochi University of Technology, Kami-shi, Kochi, Japan

Misato Inaba Graduate School of Letters, Hokkaido University, Sapporo, Hokkaido, Japan

Hajime Ishida Department of Human Biology and Anatomy, Graduate School of Medicine, University of the Ryukyus, Nishihara, Okinawa, Japan

Hiroaki Kawamichi Division of Cerebral Integration, Department of Cerebral Research, National Institute for Physiological Sciences, Okazaki, Aichi, Japan

Ryosuke Kimura Graduate School of Medicine, University of the Ryukyus, Okinawa, Japan

Ryo Kitada Division of Cerebral Integration, Department of Cerebral Research, National Institute for Physiological Sciences, Okazaki, Aichi, Japan

Yasushi Kobayashi Department of Anatomy and Neurobiology, National Defense Medical College, Tokorozawa, Saitama, Japan

Takanori Kochiyama The Hakubi project, Primate Research Institute, Kyoto University, Inuyama, Aichi, Japan

Brain Activity Imaging Center, Advanced Telecommunications Research Institute International, Kyoto, Japan

Osamu Kondo Department of Biological Sciences, Graduate School of Science, University of Tokyo, Tokyo, Japan

Tadashi Koyama Department of Human Psychology, Faculty of Humanities and Sciences, Kobe Gakuin University, Kobe, Hyogo, Japan

Daisuke Kubo Department of Biological Sciences, Graduate School of Science, University of Tokyo, Tokyo, Japan

Toshiyasu Matsui Department of Anatomy and Neurobiology, National Defense Medical College, Tokorozawa, Saitama, Japan

George Matsumura Department of Anatomy, Kyorin University School of Medicine, Tokyo, Japan

Masahiro Matsunaga Division of Cerebral Integration, Department of Cerebral Research, National Institute for Physiological Sciences, Okazaki, Aichi, Japan

Alex Mesoudi Department of Anthropology and Centre for the Coevolution of Biology and Culture, Durham University, Durham, UK

Takashi Michikawa Research Center for Advanced Science and Technology, University of Tokyo, Tokyo, Japan

Keita Mitani Kochi University of Technology, Kami-shi, Kochi, Japan

Steven Mithen University of Reading, Whiteknights, Reading, UK

Naoki Miura Department of Information and Communication Engineering, Faculty of Engineering, Tohoku Institute of Technology, Sendai, Miyagi, Japan

Kei Mizuno Molecular Probe Dynamics Laboratory, RIKEN Center for Molecular Imaging Science, Kobe, Hyogo, Japan

Pathophysiological and Health Science Team, RIKEN Center for Life Science Technologies, Kobe, Hyogo, Japan

Masaki Moriguchi Department of Information and System Engineering, Chuo University, Tokyo, Japan

Yusuke Morita Department of Mechanical Engineering, Faculty of Science and Technology, Keio University, Yokohama, Kanagawa, Japan

Sadayuki Murayama Department of Radiology, Graduate School of Medicine, University of the Ryukyus, Nishihara, Okinawa, Japan

Kenji Nagai Department of Historic Heritage, Tohoku University of Art and Design, Yamagata, Japan

Hiroyasu Nagano Department of Mechanical Engineering, Faculty of Science and Technology, Keio University, Yokohama, Kanagawa, Japan

Masato Nakatsukasa Laboratory of Physical Anthropology, Graduate School of Science, Kyoto University, Sakyo, Kyoto, Japan

Naomichi Ogihara Department of Mechanical Engineering, Faculty of Science and Technology, Keio University, Yokohama, Kanagawa, Japan

Yutaka Ohtake Department of Precision Engineering, University of Tokyo, Tokyo, Japan

Keiichi Omura Studies in Language and Culture, Graduate School of Language and Culture, Osaka University, Toyonaka, Osaka, Japan

Ryoichi Onoda Graduate School of Letters, Hokkaido University, Sapporo, Hokkaido, Japan

Satoshi Oota RIKEN BioResource Center, Tsukuba, Ibaraki, Japan

Norihiro Sadato Division of Cerebral Integration, Department of Cerebral Research, National Institute for Physiological Sciences, Okazaki, Aichi, Japan

Akihiro Sasaki Division of Cerebral Integration, Department of Cerebral Research, National Institute for Physiological Sciences, Okazaki, Aichi, Japan

Dora Simunovic Graduate School of Letters, Hokkaido University, Sapporo, Hokkaido, Japan

Hiromasa Suzuki Research Center for Advanced Science and Technology, University of Tokyo, Tokyo, Japan

Haruka Takahashi Division of Cerebral Integration, Department of Cerebral Research, National Institute for Physiological Sciences, Okazaki, Aichi, Japan

Nobuyuki Takahashi Center for Experimental Research in Social Sciences, Graduate School of Letters, Hokkaido University, Sapporo, Hokkaido, Japan

Hiroki C. Tanabe Department of Social and Human Environment, Graduate School of Environmental Studies, Nagoya University, Nagoya, Aichi, Japan

Division of Cerebral Integration, Department of Cerebral Research, National Institute for Physiological Sciences, Okazaki, Aichi, Japan

Hideaki Terashima Department of Human Psychology, Faculty of Humanities and Sciences, Kobe Gakuin University, Kobe, Hyogo, Japan

Eiko Yamagami Department of Human Psychology, Faculty of Humanities and Sciences, Kobe Gakuin University, Kobe, Hyogo, Japan

Taro Yamauchi Laboratory of Human Ecology, Faculty of Health Sciences, Hokkaido University, Sapporo, Hokkaido, Japan

Mika Yamazaki Child Development Research Center, Graduate School of Medical Sciences, National University Corporation University of Fukui, Fukui, Japan

Akira Yogi Department of Radiology, Graduate School of Medicine, University of the Ryukyus, Nishihara, Okinawa, Japan

Yumiko Yoshida Division of Cerebral Integration, Department of Cerebral Research, National Institute for Physiological Sciences, Okazaki, Aichi, Japan

Kazufumi Yoshihara Department of Psychosomatic Medicine, Graduate School of Medical Sciences, Kyushu University, Fukuoka, Japan

Introduction

1

Naomichi Ogihara, Hiroki C. Tanabe, Hideaki Terashima, and Takeru Akazawa

The "Replacement of Neanderthals by Modern Humans" (RNMH) project aims to validate the working hypothesis, or "learning hypothesis," that seeks to explain the replacement of Neanderthals (*Homo neanderthalensis*) by early modern humans (*H. sapiens*). The RNMH project focuses on evidence—such as innate differences in learning capacity between the two populations—within an interdisciplinary research framework that incorporates new perspectives and methods from the humanities and biological sciences, including neuroscience and engineering. This volume, the second of a two-volume book, is the result of papers presented at the first international conference of the RNMH project, held in Tokyo in November 2012. The first volume covers cultural perspectives addressing the process of the replacement of Neanderthals and learning strategies based on changing patterns in archaeological evidence and theoretical interpretation using mathematical models. The second volume deals with cognitive and physical perspectives on the replacement process, exploring the innate differences in learning and cognitive abilities that may have existed between Neanderthals and early modern humans. The editors of the second volume have selected a total of 26 contributed papers, divided into four parts according to research topic.

The first part is devoted to cognitive and psychological perspectives on the learning hypothesis. Here, the authors work to clarify which cognitive and psychological functions helped shape the fate of the two species. Mithen (Chap. 2) reviews the similarities and differences in cognition of Neanderthals and early modern humans and discusses the possible differences in cognitive ability between them, offering examples such as the use of pigment. The next two chapters deal with learning style and ability in modern humans. Ando (Chap. 3) introduces three learning types, individual, imitative and instructed, and discusses the differences in their characteristics based on original experiments. Omura (Chap. 4) considers the evolutionary basis for theories on learning ability in modern humans, modifying the cumulative cultural evolution hypothesis proposed by Tomasello, and proposes that the most important ability for cumulative cultural learning is the ability to objectify and manipulate the relationships between culture and the environment. The subsequent two chapters report field research conducted with children. It is important to understand the basic learning characteristics required for modern humans to survive as innovative hunter-gatherers. In particular, it is critical to focus on the learning behaviors seen in children and children's play groups, since childhood is the most active period for learning, and because play groups served as the primary learning place for children until the introduction of modern school education. Koyama (Chap. 5) and Yamagami (Chap. 6) joined Baka society in Cameroon and performed experiments with Baka children. They found evidence of cognitive flexibility as demonstrated by object-making and drawings, which might be important in the construction of a flexible learning attitude in modern humans. The last two chapters of the first part of this volume offer experimental psychological evidence.

N. Ogihara (✉)
Department of Mechanical Engineering, Faculty of Science and Technology, Keio University, 3-14-1 Hiyoshi, Kohoku-ku, Yokohama, Kanagawa 223-8522, Japan
e-mail: ogihara@mech.keio.ac.jp

H.C. Tanabe
Department of Social and Human Environment, Graduate School of Environmental Studies, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, Aichi 464-8601, Japan

Division of Cerebral Integration, Department of Cerebral Research, National Institute for Physiological Sciences, 38 Nishigo-naka, Myodaiji, Okazaki, Aichi 444-8585, Japan
e-mail: htanabe@lit.nagoya-u.ac.jp

H. Terashima
Department of Human Psychology, Faculty of Humanities and Sciences, Kobe Gakuin University, 518 Arise, Ikawadani-cho, Nishi-ku, Kobe, Hyogo 651-2180, Japan
e-mail: terasima@human.kobegakuin.ac.jp

T. Akazawa
Research Institute, Kochi University of Technology, 185 Miyanokuchi, Tosayamada, Kami-shi, Kochi 782-8502, Japan
e-mail: akazawa.takeru@kochi-tech.ac.jp; akazawa0823@qd6.so-net.ne.jp

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Evolutional mathematical models assume that there are two types of learning process: individual learning (i.e., learning by oneself, by trial-and-error) and social learning (i.e., learning from others, by imitation). However, from a cognitive psychology viewpoint, this dichotomy might be misleading or inadequate, because there are more cognitive factors operating in the learning situation. Takahashi et al. (Chap. 7) claim that individual learning has two different components: trial-and-error and creativity. They clarify the relationship between the abilities of imitation, trial-and-error, and creativity from an experimental psychology point of view. Mesoudi (Chap. 8) investigates social and individual learning behavior in an archaeological context, examining how contemporary humans behaved when faced with a relatively complex and novel technology design task and elucidating their adaptive performance under constraint.

The second part of this volume deals with biology and genetics as related to the replacement of Neanderthals by modern humans. Hoshino et al. (Chap. 9) present a preliminary analysis of the three-dimensional kinematics of knapping motion in stone tool-making. Such replication studies are important for identifying the motor skills required for recurrent Levallois techniques, as well as possible differences in learning ability between Neanderthals and early modern humans. Hagino and Yamauchi (Chap. 10) and Yamauchi and Hagino (Chap. 11) report the results of field studies on Baka hunter-gatherers. In Chap. 10 the authors quantify the daily physical activities and time-space of hunter-gatherers' children, and in Chap. 11 they compare the growth patterns of hunter-gatherer children with those of populations in other parts of the world. These studies provide a solid biological basis for understanding and characterizing learning behavior in hunter-gatherer societies, allowing extrapolation to potential differences in learning ability between Neanderthals and early modern humans. In the last paper in the second part of this volume, Kimura (Chap. 12) discusses statistical analyses of population genomics. Reconstructing modern human population dispersal is crucial for understanding the replacement of Neanderthals by early modern humans, and Kimura's computer simulation study represents a step towards better interpretation of results obtained by genetic analyses for the reconstruction of the complex demographic history of modern human populations.

The third part of this volume contains studies on the computerized reconstruction of fossil crania and brain morphology, which is expected to facilitate empirical validation of the learning hypothesis by providing anatomical proof of differences in learning ability between Neanderthals and early modern humans. Bruner (Chap. 13) reviews recent advances in functional craniology in Neanderthals and demonstrates that Neanderthals generally display a plesiomorphic organization of the braincase. Bruner hypothesizes that a morphogenetic limit (caused by geometric and structural constraints between the endocranial soft and hard tissues) and a thermal limit (rooted in the plesiomorphic vascular system) led to differences in cranial morphology between Neanderthals and early modern humans. Kobayashi et al. (Chaps. 14 and 15) present their attempts to establish a connection between cranial and brain morphology in extant macaques. In Chap. 14, they report that endocasts of macaque skulls show marked impressions of the cerebral sulci and gyri through the entire surface, indicating that the extent of major subdivisions of the macaque cerebral cortex can be determined from endocasts. In Chap. 15, the authors present their results on the morphological correspondence between the location of sutures and the location of major sulci. These studies provide important data for the estimation of brain morphology based on fossil crania.

The next four papers in the third part of the volume focus on geometric morphometrics for the digital reconstruction of fossil crania. Geometric morphometrics is a quantitative approach used to analyze shape variations based on landmark coordinates. However, the human cranial vault has few definable landmarks, and semi-landmarks must be introduced for quantification of the overall shape of the cranial vault. Using the modern Japanese population as an example, Ogihara et al. (Chap. 16) evaluate how two types of semi-landmark configurations affect the analysis of morphological variability in neurocranial shape, concluding that the results do not seem to be significantly affected by the choice of landmark configuration, provided that a sufficient number of semi-landmarks are evenly distributed across the neurocranial surface. Morita et al. (Chap. 17) also focus on the modern Japanese population, analyzing the detailed morphological variability of cranial shape using geometric morphometrics. The results presented by Morita et al. serve as a reference database of human cranial morphology for computerized reconstruction of fossil crania, such as the assembly of fossil cranial fragments and the interpolation of missing parts in fossil crania. Using this cranial database, Amano et al. (Chap. 18) propose a method for mathematically interpolating missing parts of crania, and discuss the usefulness and limitations of the proposed interpolation method for the reconstruction of fossil crania. In the above three studies, semi-landmarks were placed by sliding a "template" landmark configuration along the cranium in order to minimize spatial bending energy. However, Moriguchi et al. (Chap. 19) proposes a new approach to the transfer of semi-landmarks based on the minimization of bending energy on the surface.

The final three chapters in the third part of this volume deal with the reconstruction of fossil crania and brain morphology. Suzuki et al. (Chap. 20) propose an automatic CT segmentation method using structural analysis for the disassembly of fragments of an assembled fossil cranium in order to permit reassembly of the fragments. The proposed method would be a valuable tool for the digital reassembly of fossil materials. Kondo et al. (Chap. 21) present a semi-virtual method for the reconstruction of the endocast of Qafzeh 9, a representative early modern human fossil, using CT images, and discuss possible asymmetries found in the cranial morphology. Lastly, Kochiyama et al. (Chap. 22) propose a framework for a computerized method of digitally reconstructing Neanderthal brain morphology. Specifically, mapping from a human cranium to a fossil cranium was defined by means of a spatial deformation function using computational anatomy methodology, and this function was then applied to the estimation of the shape of the brain inside the fossil cranium. Although this method has methodological limitations that have yet to be resolved, the proposed framework is promising for application to the mathematical reconstruction of fossil brain morphology.

The fourth and final part of this volume is devoted to neuroscience. The authors adopt cognitive neuroscientific and computational neuroanatomical approaches to search for weaknesses in the learning hypothesis. By assuming that morphological changes in fossil skulls reflect functional differences between the brains of modern humans and those of Neanderthals, the authors seek out possible gaps in learning abilities based on differences in brain morphology and region-specific activities. Tanabe et al. (Chap. 23) introduce a scheme for comparing the Neanderthal brain to the modern human brain using computational neuroanatomy and functional neuroimaging techniques, and illustrate their attempt to elucidate the difference between the two species. As an example of this approach, Kubo et al. (Chap. 24) show the correlation between the cerebellar and posterior cranial fossa volumes using structural magnetic resonance imaging data, and attempt to develop a method for estimating the cerebellar volume of fossil hominins.

Tanabe et al. (Chap. 23) also clarify which brain functions relate to learning ability under focus. The authors assume that the formation of innovative activities is strongly correlated with two components of cognitive ability: the intrinsic drive (internal motivation and perspective) to produce creative activity, and the social cognitive ability to make predictions about the actions and intentions of others on the basis of their mental states. Early modern humans might have been superior to Neanderthals in these abilities and this difference may have determined the fates of both species. Based on this hypothesis, Tanabe et al. attempt to identify functional brain maps related to social cognition and motivation, and clarify the neural mechanisms of eye contact and joint attention, which are both markers of social cognitive ability during early development in humans. Kawamichi et al. (Chap. 25) examine the neural correlates of sense of acceptance, which is thought to be one of the key factors for maintaining an innovative society. Miura et al. (Chap. 26) identify the neural substrates of imitative learning of stone tool-making actions, and Mizuno (Chap. 27) examines the neural substrates associated with motivation to learn. These studies contribute to the creation of maps of specific brain functions. Using this input, it is possible to examine the differences in learning abilities between Neanderthals and early modern humans by integrating morphological analyses of fossilized brains with functional mapping of the modern human brain.

We hope this edited volume will promote further integration of different disciplines and enrich ongoing discussions to promote better understanding of the dynamics of learning in the replacement of Neanderthals by early modern humans.

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