

Replacement of Neanderthals by Modern Humans: Testing Evolutionary Models of Learning

November 30–December 6, 2014, Date City









Program and Abstracts

Edited by Takeru Akazawa & Yoshihiro Nishiaki



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RNMH Project Series

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Published by

RNMH Project Group Research Institute, Kochi University of Technology CIC Tokyo, 3-3-6 Shibaura, Minato-ku, Tokyo 108-0023, Japan Tel: +81-(0)3-5440-9039 Fax: +81-(0)3-5440-9119 http://www.koutaigeki.org/

The publication of the RNMH Project Series has been supported by a Grant-in-Aid for Scientific Research on Innovative Areas (Grant No. 22101001) from Japanese Ministry of Education, Culture, Sports, Science and Technology.

ISBN: 978-4-9906371-0-1

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Produced by Akita Kappan, Inc., Akita

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Preface

RNMH2014 is the second international conference for our major research project entitled "Replacement of Neanderthals by Modern Humans: Testing Evolutionary Models of Learning" (RNMH). Similar to the first conference held in Tokyo, Japan in 2012, this one aims to compile the latest research investigating the issues surrounding the replacement of those two populations.

Understanding this phenomenon of replacement, including clarification of its detailed spatio-temporal processes and interpretation of the mechanism(s) behind them, has been one of the most hotly debated subjects in the recent anthropological literature. Even in the few years directly after launching the RNMH project in 2010, a series of influential findings were newly reported. For example, particularly remarkable achievements were based on ancient genetic studies. DNA analyses of fossil and Modern Human remains have demonstrated the possible occurrence of interbreeding between Neanderthals and anatomically Modern Humans in the Paleolithic period.¹ Likewise, the presence of another indigenous population in Paleolithic Eurasia, the Denisovans, was identified in eastern Central Asia where the occurrence of Neanderthals was also known.² On the other hand, archaeological fieldwork has also continuously yielded new insights. Discoveries indicating "modern" Neanderthal behaviors that were previously attributed only to anatomically Modern Humans are at most interesting,³ blurring the behavioral distinction between these two populations.

These and other new data indicate that the replacement processes should be considered more complicated than before, certainly rejecting a simple straightforward "replacement" model. At the same time, varied processes, and hence varied mechanisms in each region should be considered. In other words, research in this area today requires more refined perspectives grounded in interpretation of higher resolution data. This recognition is related to one of the two main objectives of this conference, which is giving an opportunity for international colleagues to gather and present state-of-the-art results on these subjects. This opportunity should also be welcomed by RNMH project members to present their research results in an international arena to solicit expert evaluation.

The second objective of this conference is to discuss the working hypothesis proposed by the RNMH project, coined as the "learning hypothesis." The specific goal of this project is to verify this hypothesis within an interdisciplinary research framework incorporating new perspectives and methods from the humanities and biological sciences. It is unique in focusing on possible differences in learning (abilities/strategies/behaviors) between Neanderthal and Modern Human societies. The hypothesis was based on the following reasoning: success or failure of any human society is heavily dependent on culture; culture is transmitted, maintained, and modified through learning; and this premise is probably applicable to human societies during the replacement period as well. Was there any significant difference in learning between Neanderthals and anatomically Modern Humans? If so, clarification is required to explain how and whether it derived from their innate biological difference, social environments, or from both factors. Although the detailed answers will be obtained after much research to come, we believe that it is a significant advantage to look at the broader replacement processes, thus enlarging the dimensions of current debates.

Spanning seven days between November 30 and December 6, the conference consists of three major parts. After the opening remarks and keynote lectures on Day 1 (November 30), when the latest findings in physical anthropology, cognitive archaeology, and field archaeology are addressed, the first part starts on Day 2 (December 1) and continues until Day 3 (December 2). It deals with the behavioral characterization of these two populations and the details of replacement processes by region as revealed through a variety of disciplines including prehistoric archaeology, ecology, genetics, and palaeoenvironments. The regional survey focuses on West Asia and Europe, where the processes have been most intensively studied, but it also refers to new data from Africa and Central and East Asia. Following a break for the excursion on Day 4 (December 3), the second subject, learning, will be covered on Day 5 (December 4). Possible differences in learning abilities, strategies, and behaviors between Neanderthals and Modern Humans are discussed using evidence from fieldwork in archaeology, cultural anthropology, and primatology. Theoretical modeling to predict evolutionary paths in learning strategies will also be addressed. In the final part on Day 6 (December 5), sessions will be devoted to discussing the innate learning capabilities among these hominin populations. Instead of considering behavioral evidence reflected in the archaeological records, the discussion focuses on independent evidence obtained through innovative approaches to studying the available cranial endocasts of Neanderthals and anatomically Modern Humans. The conference closes after the post-conference excursion on Day 7 (December 6).

RNMH2012, Tokyo, consisted of 30 oral and 38 poster presentations. RNMH2014 incorporates 55 oral and 22 poster presentations. In addition to changes in the conference structure and number of presentations, we are pleased to see the remarkable increase in the range of countries in which participants are based (6 to 16). This certainly reflects the worldwide increase in research interest on these topics. The organizers are deeply indebted to all participants, especially those visiting from overseas who made RNMH2014 a truly international platform.

Last but not least, we would like to mention that financial support for RNMH2014 has been obtained from the Ministry of Education, Culture, Sports, Science and Technology, Japan (Grant No. 22101001) and the Education Board of Date City, Hokkaido. Our deepest gratitude is extended to the Date Volunteer Society for Scientific Meeting, who organized the venue for this international meeting.

Takeru Akazawa Kochi University of Technology Yoshihiro Nishiaki The University of Tokyo

^{1.} Green RE et al (2010) A draft sequence of the Neandertal genome. Science 328: 710-722.

^{2.} Krause J et al (2010) The complete mitochondrial DNA genome of an unknown hominin from southern Siberia. Nature 464: 894–897. Reich D et al (2010) Genetic history of an archaic hominin group from Denisova Cave in Siberia. Nature 468: 1053–1060.

^{3.} Villa P, Roebroeks W (2014) Neandertal demise: An archaeological analysis of the Modern Human superiority complex. PLoS One. doi: 10.1371/journal. pone.0096424

RNMH2014

The Second International Conference Replacement of Neanderthals by Modern Humans: Testing Evolutionary Models of Learning

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CONFERENCE PROGRAM

DAY 1: November 30 (Sunday), 2014 11:00-17:00 Registration

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	Will we Modern Humans fade away or be replaced?	

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13:40-14:30	Silvana Condemi	019
	From Neandertals to Modern Humans: A view from the Italic Peninsula	
14:30-15:20	Thomas Wynn and Frederick L. Coolidge	021
	The expert performance model of Neandertal cognition	
15:20-15:35	Coffee break	
15:35-16:25	Marcel Otte	023
	Neandertal: Abilities and realisations	
16:25-16:30	Break	
16:30-17:00	Discussion	
17:30	Free bus service to the Toyako Manseikaku Hotel Lakeside Terrace	

Welcome party

18:00-19:30 Toyako Manseikaku Hotel Lakeside Terrace

DAY 2: December 1 (Monday), 2014 9:30-17:00 Registration

Neanderthals and Modern Humans: Behavioral Characterization

Chair: Seiii Kadowaki

· · · · · · · · · · · · · · · · · · ·		
10:00-10:25	Michael Chazan, Francesco Berna, Steven Walker, Ian Watts, Jayne Wilkins and	
	Liora Kolska Horwitz	.026
	The development of technology during the Earlier Stone Age: Research at Wonderwerk Cave and	
	the Kathu Complex, Northern Cape Province, South Africa	
10:25-10:50	Ran Barkai	.029
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10:50-11:15	Avraham Ronen	.031
	Middle Palaeolithic flint mines in Mount Carmel: An alternative interpretation	
11:15-11:40	Gonen Sharon	.034
	A week (?) in the life of the Mousterian hunter	
11:40-12:05	Taro Yamauchi	.036
	Evolution of learning capacity and acquired behaviors of Modern Humans from the perspective of	
	life history and brain development	
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The First RNMH Processes in West Asia

Chair: Katsuhi	ro Sano	
13:50-14:15	Mina Weinstein-Evron, Yossi Zaidner, Alexander Tsatskin, Reuven Yeshurun and	
	Israel Hershkovitz	038
	The Early Middle Paleolithic of Misliya Cave, Mount Carmel, Israel	
14:15-14:40	Yossi Zaidner, Laura Centi, Marion Prevost, Maayan Shemer and Oz Varoner	039
	Preliminary study of the lithic assemblages from Nesher Ramla: A case of continuity and	
	change in the Levantine Middle Paleolithic	
14:40-15:05	Andrew W. Kandel and Ron Shimelmitz	040
	Technological trends of the Middle to Upper Paleolithic transition at Sefunim Cave, Israel	
15:05-15:30	Nigel Goring-Morris and Anna Belfer-Cohen	043
	The Ahmarian in the context of the earlier Upper Palaeolithic in the Near East	
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Chair: Yasuhis	sa Kondo	
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	The Upper Palaeolithic of Manot Cave, western Galilee, Israel	
16:15-16:40	Andreas Taller, Boris Gasparyan and Andrew W. Kandel	045
	Living on the edge: The earliest Modern Human settlement of the Armenian Highlands	
16:40-17:05	Fereidoun Biglari	048
	Typo-technological analysis of the Late Middle Paleolithic bifacial industry of	
	Qaleh Bozi Rockshelter, Central Iran	
17:05-17:30	Sonia Shidrang	051
	The Middle to Upper Paleolithic transition in Zagros: The appearance and evolution of Barado	stian in
	the light of new research	
18:00	Free bus service to the Toyako Manseikaku Hotel Lakeside Terrace	

DAY 3: December 2 (Tuesday), 2014 9:30-17:00 Registration

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Ghair. Millioru Toneua	Chair:	Minoru	Yoneda
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10:00-10:25	Wonsuh Song, Yasuhisa Kondo and Takashi Oguchi	056
	Presentation of the PaleoGeo database with Google Earth	
10:25-10:50	Stephen P. Obrochta, Yusuke Yokoyama and Hodaka Kawahata	059
	Regional last glacial climate synthesis for the Eastern Mediterranean	
10:50-11:15	Ryouta O'ishi,Wing-Le Chan and Ayako Abe-Ouchi	
	Vegetation change in Europe during the Late Pleistocene dispersal of Modern Humans	
11:15-11:40	Yasuhisa Kondo	
	Cost surface analysis based on ecological niche probability to estimate relative rapidity of the	dispersals of
	early Modern Humans	

Timing of the RNMH in Europe

Chair: Olaf Jöris

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	Introduction to the "PalaeoChron" Project: Chronological mapping of the Middle and early Upper	
	Palaeolithic of Eurasia	
12:05-12:30	Tom Higham	065
	Radiocarbon dating the final Mousterian of Eurasia using advanced chemistry methods	
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Chair: Fereidoun Biglari

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	Takehiro Miki, Takayuki Omori and Jannat Ismailova	.073
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	Takao Sato, Kenji Suzuki and Hirofumi Kato	.075
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18:00	Free bus service to the Toyako Manseikaku Hotel Lakeside Terrace	

DAY 4: December 3 (Wednesday), 2014 9:30-17:00 Registration

Excursion (optional)

10:00	Toyako Manseikaku Hotel Lakeside Terrace
10:10	Volcano Science Museum
12:00	Lunch at Shiraoi
13:00	Ainu Museum Poroto Kotan
17:00	Toyako Manseikaku Hotel Lakeside Terrace

Learning Strategies and Cultural Evolution – Archaeological Approach

Chair: Nigel Goring-Morris

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13:00-13:30	Poster session	

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Chair: Hideaki Terashima

13:30-13:55	Bonnie Hewlett	
	Innovation, processes of social learning and modes of cultural transmission amongst the Cha	abu
	adolescent forager-farmers of Ethiopia	
13:55-14:20	Barry S. Hewlett	
	Cognition and cultural niche construction among Neanderthals and Modern Humans	
14:20-14:45	Nobutaka Kamei	
	Theoretical and ethnographic studies on play and learning behaviors: The case of hunter-gatherer	children in
	the forest	
14:45-15:10	Takeshi Furuichi, Crickette Sanz, Kathelijne Koops, Tetsuya Sakamaki, Heungjin Ryu,	
	Nahoko Tokuyama and David Morgan	
	Why do wild bonobos not use tools like chimpanzees do? Examination of factors influencing the t	ool behaviors
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Learning Strategies and Cultural Evolution – Perspectives from Theoretical Modelling Chair: Kenichi Aoki

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Chair: HIROKI C.	anabe	
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Looking into the Neanderthal Brain

Chair: Naomichi Ogihara

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DAY 7: December 6 (Saturday), 2014

Post-conference Excursion (optional)

9:00	Toyako Manseikaku Hotel Lakeside Terrace
11:30	Lunch at Nibutani
12:30	Shigeru Kayano Memorial Museum, Saru Historical Museum and Ainu Cultural Museum
	Lecture by Jun Takakura, Hokkaido University: Prehistory of the Hokkaido Island
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DAY 1: November 30, 2014

Keynote Lectures

Will we Modern Humans fade away or be replaced?

Takeru Akazawa

Research Institute, Kochi University of Technology, Japan. Email: akazawa0823@qd6.so-net.ne.jp

We humans, what are we? Various approaches to answering this question come to mind. One possibility is to investigate, through the numerous fossils of now-extinct hominids, how those hominids lived their lives. This should provide some understanding of the path by which we have come to be who we are today. Among those fossil hominids, there is much to be learned from the Neanderthals in particular, since they were the last hominid population on Earth before Modern Humans took over.

Modern Humans appeared in Africa about 200,000 years ago. Later, as they spread across Eurasia, they encountered indigenous Neanderthal populations. The two populations coexisted until 30,000 years ago, perhaps even later, but the Neanderthals eventually went extinct. The question has long occupied us: what happened to the Neanderthals? A number of current hypotheses propose 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.

Whenever human evolution reached such a fork, a new instance of humanity thrived while an old instance became extinct. In the last of these recurring succession dramas, the humans closest to us today, the modern *Homo sapiens*, thrived while the earlier humans, archaic *H. sapiens* met their demise. All humans currently inhabiting the earth are descendants of the anatomically modern *H. sapiens* who survived that epic transformation; now it is entirely possible that they are in midcourse towards the next succession event.

We can imagine the disappearance of today's Modern Humans and their replacement by some new branch of the human family, but no one knows what that new branch might be, nor can we concretely envision the nature of that new succession event. One long-term goal of humans, an abstract one, is to come to an understanding of the varied forms of existence we have experienced during our evolution. This quest may be of monumental importance: essential clues to an understanding of our future may lie hidden in our past.

From Neandertals to Modern Humans: A view from the Italic Peninsula

Silvana Condemi

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As in other regions of Europe, the presence of the Neandertal population on the Italian peninsula has been well documented for a long time. The first evidence of Mousterian assemblages that, in Europe, were considered to have been made solely by Neandertals, was identified at the end of the 19th century (in 1889) at the site of Fate on the Italian riviera. The first Neandertal human fossil discovery occurred fortuitously in 1929, when the nearly complete cranium of Saccopastore 1 was unearthed in the city of Rome. During the following decade, this first discovery was augmented by that of two other major Italian fossils: Guattari 1, found in 1935 at the promotorium of Circeo (90 km south of Rome), and Saccopastore 2, unearthed in 1939 in the city of Rome. Although, once again, these two Neandertal crania were discovered by chance, and they lack of precise stratigraphic context, they have contributed to our understanding of the Neandertals of southern Europe.

After a long interruption of research and exploration during the Second World War and the decade that followed, excavations were begun throughout the central, northern and southern regions of the Italian peninsula after the middle of the 1950s. At present, only a few excavations related to the middle and upper Pleistocene are still in progress.

All research and study of the fossils and material uncovered by these excavations have permitted us to establish a similarity in the history of the Italian Neandertals to that in other parts of Europe: after having lived and thrived in Europe from MIS7 to MIS3, Neandertals then disappeared, leaving only Homo sapiens.

Although no verifiable Homo sapiens fossils from MIS3 have been found in Europe, their arrival is assumed due to the presence of Aurignacian assemblages, the most ancient of which have been identified in eastern Europe. From east to west, the dispersal of Homo sapiens resulted in the replacement of the local Mousterian Neandertal population. In some cases, the Neandertal population was pushed toward marginal geographical areas, notably toward the Iberian and Italian peninsulas.

During this process that occurred over a period of several thousand years, it was believed that the influence of Homo sapiens in Europe led some Neandertal groups to modify their behavior and their way of life (d'Errico et al. 1999) and, in particular, to change their Mousterian assemblages and produce what is often termed "transitional" assemblages (Szeletian, Chatelperronian, Uluzzian ...). The assumption that Neandertals produced all "transitional assemblages" was based on the well-preserved Neandertal remains at Saint Césaire that were believed to have been associated with the Chatelperronian in southwestern France.

The hypothesis of a long period of Neandertal survival in marginal areas has found support in Spain due to the dates of Mousterian Neandertal sites (Finlayson et al. 2006) and, on the Italian peninsula, in view of the presence of a "transitional", Uluzzian assemblage limited to the central and southern parts of the peninsula. The presence of Uluzzian culture (characterized by personal ornaments, bone tools and dyes) solely in the central and southern regions of the Italian peninsula reinforced the impression that Neandertals who were pushed out found refuge in this geographic area, where they continued to survive and began to make a "new" kind of assemblage influenced by the technology of the incoming Homo sapiens. Indeed, according to this scenario, the Uluzzian assemblages

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found on the Italian and Balkan peninsulas were considered to be comparable to the Chatelperronian assemblages found in France and in northern Spain. Since it was believed that the Chatelperronian was produced by late Neandertals, it was assumed that Neandertals also made Uluzzian assemblages (Churchill et al. 2000).

In recent years this scenario has been completely overturned. First, the discovery of Uluzzian assemblages also on the northern Italian peninsula, at the site of Fumane (Peresani 2008) shows that this kind of assemblage was less confined to the south than had been supposed. Second, the new AMS dates of a Mousterian Neandertal site, Riparo Mezzena near Fumane, indicate that Mousterian Neandertals may have survived longer than had been thought (Longo et al. 2012).

Third and most important, however, is the re-analysis of the only human remains associated with Uluzzian archaeological layers, two teeth from Grotta del Cavallo in the southern Italian peninsula found in 1964. In this study (Benazzi et al. 2011), the teeth from Cavallo were compared by means of CT scans with those from a large Modern Human and Neanderthal dental sample. The internal and external features of the dental crown, including the thickness of the enamel and the general outline of the crown, were submitted to examination. The results showed that the human teeth from Grotta del Cavallo were Modern Humans, not Neanderthals as had originally been thought. Furthermore, since the teeth were too small and precious to date directly, chronometric analysis was carried out on marine shells found in the same archaeological levels as the teeth. This approach showed the date of the Modern Human teeth to be between ~43,000-45,000 years ago (cal BP). This means that the human remains are older than any other Modern Humans discovered in Europe and that these two teeth from Grotta del Cavallo therefore represent the oldest European Modern Human fossils currently known. The study of the teeth of Grotta del Cavallo confirms that the arrival of our species on the European continent, and the period of their coexistence with Neanderthals, was several thousand years longer than was previously thought. Based on this fossil evidence, this study also confirms that Modern Humans and not Neanderthals were the makers of the Uluzzian culture and that the colonization of the European continent by Homo sapiens occurred in successive waves.

Each of these three points is currently a topic of debate, which has been fueled by criticism regarding the chronostratigraphy of the Italian sites. The aim of our paper is to present the complex archeological data originating from the Italian peninsula and to discuss problems and criticism which current studies of these sites are likely to face.

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The expert performance model of Neandertal cognition

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With recent archaeological discoveries of Neandertal ornaments (Zilhao et al. 2010), the time-worn argument that Neandertals lacked symbolic culture is effectively defunct. Nevertheless, despite the many similarities between the archaeological signatures of Neandertals and same-age Modern Humans, there are still apparent differences. Some of these differences, such as Neandertals' lower levels of innovation, suggest that there was a modest but significant cognitive difference between Neandertals and same-age Modern Humans (contra Villa and Roebroeks 2014).

One way to understand this difference is to apply a formal model of cognition. For several decades cognitive psychologists have studied a domain of thinking termed 'expert performance' which comes to the fore in welllearned, narrowly circumscribed activities such as chess and music. Several formal models have been proposed, all of them focused on an expert's ability to rapidly access large amounts of information held in long-term memory. The specific model we have chosen to use is that of Anders Ericsson (K. Ericsson and Delaney 1999; K. A. Ericsson and Kintsch 1995), largely because it incorporates working memory, a well-known cognitive ability that the two of us have applied effectively to the study of recent cognitive evolution (Coolidge and Wynn 2005; Wynn and Coolidge 2004). Ericsson's model revolves around 'retrieval structures,' which are sets of cues held in working memory that are linked to much larger encodings held in long-term memory (as when the retrieval structure 'King's Indian Defense' has cues linking to the locations of 32 chess pieces on the 64 square board for several successive moves). These retrieval structures are largely non-symbolic, and are learned by practice and repetition, i.e., apprenticeship. Coincidentally, Keller and Keller (1996) have documented the kind of thinking used by artisan blacksmiths, and their description is very similar to Ericsson's account of expertise. When Keller and Keller's ethnographic account of technical cognition is combined with Ericsson's psychological account of expert cognition, the result is a powerful model of expert technical cognition that is directly applicable to the archaeological record. Using this model we are able to account for many of the similarities and differences presented by the archaeological signatures of Neandertals and same-age Modern Humans. In brief, Neandertals appear to have relied very heavily on expert cognition as the basis for not just their technology, but also their hunting and gathering.

This "Ericsson-Keller" model of technical cognition helps us understand the apparent difference in innovation. Expert cognition powers flexible solutions to the large range of problems encountered in its narrow domain, but it does not itself generate new solutions. If, as we suspect, Neandertals relied very heavily on expert cognition, we would not expect to see much innovation, and we do not. Creativity relies on other cognitive systems, including working memory capacity and, for technology, abstract concepts of folk physics. These are abilities that were apparent for moderns, but not for Neandertals. Recent research on the role of the cerebellum in cognition suggests that Neandertals' comparatively smaller cerebellum might account for some of this lower level of creativity,

Finally, this Ericsson-Keller model is entirely consistent with the learning hypothesis as developed by Akazawa and colleagues (Akazawa et al. eds. 2013, 2014). The kinds of learning required for expert performance are quite different from the kinds of learning required for elaborate symbol-based, declarative information. Observation

and practice are the essential components, and language plays a much lesser role.

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Neandertal: Abilities and realisations

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In ever aspects of behavior, Neandertal has proven his abilities. The Levallois is the most powerful ever invented in lithic techniques. The hunting strategy was highly elaborated. Burial pratices show their metaphysic.

The only difference with Modern Man lies in their choices in the ways of life. These ways are in the context of history, not anymore in the field of physical capacity. They choose the way of life that has been working during 300,000 years.

DAY 2: December 1, 2014 Neanderthals and Modern Humans: Behavioral Characterization

Neanderthals and Modern Humans: Behavioral Characterization The First RNMH Processes in West Asia

The development of technology during the Earlier Stone Age: Research at Wonderwerk Cave and the Kathu Complex, Northern Cape Province, South Africa

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In the evolution of the genus *Homo* we cannot assume that technology is a passive expression of the cognitive capacity, or invariable behavioural repertoire, of hominin populations (Chazan 2012). Members of genus *Homo* display a capacity for technological innovation independent of speciation. Thus the relationship between technological innovation and speciation is a significant issue in the study of the evolution of genus *Homo*. In this paper I present an overview of recent research at Wonderwerk Cave and the sites of the Kathu Complex, located in the Northern Cape Province, South Africa (Fig. 1). The results of this research point to a range of technological innovations in the time range between 1.8 mya and 0.5 mya. This is a period that can be correlated with *H. erectus* in a broad definition of this species that includes *H. ergaster*. The latter end of this period corresponds with the initial appearance of the poorly defined group of hominins often described as archaic *H. sapiens*. The results emerging from research at Wonderwerk Cave and the sites of the Kathu Complex suggest that technological innovation played an active role in the dynamics of the evolution during this time period.

Wonderwerk Cave penetrates 140 meters into the dolomitic rocks on the eastern flank of the Kuruman Hills. Excavations by Peter Beaumont (Beaumont and Vogel 2006) exposed a long sequence of Earlier Stone Age (ESA) occupation in the front of the cave (Excavation 1) and an occupation attributed to the transitional (Earlier Stone Age/Middle Stone Age) Fauresmith industry at the very back of the cave (Excavation 6) (Fig. 2). Our research team has undertaken a program of study to develop an absolute chronology for Excavation 1 along with a characterization of lithic and faunal material recovered by Beaumont. In December 2013 we initiated a program of excavation at the site which will expand the excavated area and allow for the recovery of high precision spatial data. A chronology for the lower levels of Excavation 1 has been developed on the basis of paleomagnetic and cosmogenic burial age dating (Chazan et al. 2008, 2012; Matmon et al. 2012; Ruther et al. 2009) (Fig 2). The earliest level (St. 12), dating to the Olduvai event (1.96-1.78 mya) contains a small stone tool assemblage attributed to the Oldowan (Chazan et al. 2012). The first bifaces appear in St. 11 dated to 1.78-1.07 mya. In St. 10, dated to the Jarmaillo (1.07-0.99 mya), handaxes are the dominant component of the assemblage. Handaxes in St. 10 and in overlying St. 9 do not show shaping through invasive flake removals. Highly symmetrical handaxes shaped by invasive removals first appear in St. 8 and continue to dominate the assemblage through the end of the ESA sequence in St. 5. Unfortunately, St. 9-5 have not yet been dated although this is a major goal of the new program of excavation. Cleavers are found beginning is St. 10 and it is particularly interesting that a cleaver made with the Victoria West method is found in St. 9.

In addition to the evidence for developments in lithic technology, Excavation 1 has yielded evidence for the earliest known presence of fire in an in situ archaeological context. Based on a combination of micromorphology, FTIR, and macroscopic evidence on lithic and faunal remains there is clear evidence for burning in St. 10 dated to the Jaramillo (Berna et al. 2012). There is limited evidence for burning in St. 12 based on analysis of microfauna (Chazan et al. 2012).

The back of Wonderwerk Cave, Excavation 6, is poorly constrained chronologically but can be securely attributed to the Fauresmith transitional industry. The lithic component includes bifaces, blade production, and prepared

core technology. The position of Excavation 6, 140 meters from the front of the cave, and the character of the archaeological assemblage which includes in addition to stone tools non-utilitarian objects such as quartz crystals and specularite have been interpreted by Chazan and Horwitz (2010) as evidence of hominin sensitivity to the sensory properties of places and object that is the precursor to symbolic behaviour.

The sites of the Kathu Complex, located on the western flank of the Kuruman Hills, provide an opportunity to explore the Acheulean and Fauresmith in the context of high density open air sites. At the Kathu Townlands site there is a remarkable density of artifacts attributed to the Acheulean that raises questions about the nature of hominin mobility and group size (Walker et al. 2014). At the Bestwood 1 site a horizon of Fauresmith occupation is found buried below sands covering hectares providing the potential to explore hominin organization of activities across the landscape (Chazan and Wilkins et al. 2012). At Kathu Pan 1, Acheulean and Fauresmith material is found in a complex stratigraphic context effecting by the action of spring vents. The Fauresmith Stratum 4a has been dated by a combination of OSL and ESR/U-series to ca. 500kyr (Porat et al. 2009). The lithic assemblage from Stratum 4a provides early evidence of blade production and the use of stone tipped spears (Wilkins and Chazan 2012; Wilkins et al. 2012).

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Fig. 1 Map showing location of Wonderwerk and the Kathu Complex. WW: Wonderwerk; BW: Bestwood; KT: Kathu Townlands; KP: Kathu Pan.



Fig. 2 Plan of Wonderwerk Cave (Curtesy of H. Ruther) showing excavation areas.



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50m.

Fig. 4 Artifacts from the Bestwood 1 site.



A tale of three caves: The role of mammoths in Neanderthal adaptation and lifeways

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"The elephant is the largest of them all, and in intelligence approaches the nearest to man" (Bostock, J., & Riley, H. T., 1855. The Natural History. Pliny the Elder. Taylor and Francis, London)

The Paleolithic archeological record depicts complex relationship between humans and elephants, as elephants were exploited for their meat, fat and bone over hundreds of thousands of years across the old world.

The role of protein in human diet and subsistence in Paleolithic sites has been demonstrated time and again. Animal meat and fat are an excellent source for calories, and contain essential amino acids, minerals, vitamins and fatty acids.

As early as the late Pliocene we are familiar with archaeological sites containing stone tools associated with animals' bones, reflecting human activities related to butchery of animals and marrow extraction. Hence, it is commonly accepted that Acheulian, and even pre-Acheulian hominins, extracted a significant portion of the calories they consumed from animal meat and fat, and thus were actually dependent on animals for their successful survival. Hence, carnivory is a remarkable human trait accompanying the human race from its earliest stage to this very day.

Palaeolithic nutrition was based on animal meat and fat in addition to plant-based foods. Many Paleolithic sites have extensive evidence for large mammal consumption and it has been argued repeatedly that big game hunting was a principal procurement strategy, most probably accompanied by the occasional use of carcasses resulted from natural death or leftovers by other high carnivores.

The significant role of Proboscideans in Paleolithic faunal assemblages is well demonstrated in many sites in Europe, Africa and Asia. However, the dietary significance of elephants has not been thoroughly explored. We work under the assumption that during Paleolithic times Proboscideans, when available, were a constant and significant source of calories for early hominins. Notwithstanding its significance, this was only one source of calories among many other (plant based and animal based) food resources used by Paleolithic hominins. However, in our opinion, it was a primary one when Proboscideans were available.

The use of elephant bones in the Acheulian for the production of tools, particularly bifaces that resemble the characteristic stone handaxes, is clearly evident. Several Lower Paleolithic Acheulian sites, however, clearly demonstrate butchery and defleshing of elephants. Post-Acheulian as well as Mousterian sites provide further evidence for the use of Proboscideans both for dietary purposes, such as meat and marrow consumption, and for other tasks, such as bone tool production.

Proboscideans were by far the largest terrestrial animal available for Lower Paleolithic hominins. They represent an ideal food package with a perfect combination of meat and fat, as half of the potential calories are in the fat. While we have no exact data as to the extent to which elephant carcasses were utilized, the abundance of evidence for elephant utilization in Paleolithic sites is a clear indication that at least part of the elephant's potential

energetic value was extracted by early humans. This view is further supported not only by the fact that some elephant bones found in Paleolithic sites bear cut marks, but also by the fact that many bones were further fractured in order to reach the marrow, indicating further use of the bones for additional fat.

In this presentation I will present several case studies for the use of Proboscideans in Lower and Middle Paleolithic sites from the Old World, discuss the role of Elephants and Mammoths in early human adaptation, diet and culture and explore the significance of Mammoths in Neanderthal survival and life-ways. An attempt will be made to correlate between the systematic use of Mammoths by European Neandethals and knowledge transmission mechanism that has to do with the acquisition and exploitation of such gigantic mammals.

Middle Palaeolithic flint mines in Mount Carmel: An alternative interpretation

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The situation

Numerous heaps of limestone fragments around Nahal (river) Galim in north-western Mount Carmel were interpreted as residues of quarries. The benefit of the operation would be to extract flint nodules lying beneath limestone beds and the lithic production areas. Freshly extracted flint nodules are indeed better knapped than nodules collected on the surface, battered by the elements and desiccated under intense sunshine. Knapped flint nodules were taken to indicate workshops of lithic production. A few Middle Palaeolithic flint artifacts mingled in the limestone heaps suggested Middle Palaeolithic date for the quarries and the hypothesized knapping workshops (Nadel et al. 2011).

Significance

From a technological perspective, experts of the Levallois method had no doubt the ability to break a limestone bed. However, this hypothesis holds far reaching consequences on the social organization of Middle Palaeolithic hominins in the Levant. The society would be able to assemble individuals for the tedious work of quarrying (perhaps even those not in immediate need of flint). A mechanism to mobilize individuals for a communal effort reflects a social organization more advanced than generally assigned to Middle Palaeolithic hominins.

Difficulties

Two observations render, however, the quarry/workshop hypothesis problematic: first, the low density of lithic products among the limestone heaps (Nadel et al. 2011), and second, the virtual absence of clearly delineated concentrations of flint knapping residues - nodules, cores, flakes and debris. Unquestioned knapping workshops (Neolithic, for example) consist of well defined concentrations of knapping residues (Ronen and Davies 1970; Taute 1994).

Another interpretation

An alternative interpretation of the Mount Carmel limestone heaps is offered here. While admitting the anthropogenic origin of the heaps, this interpretation questions their function and the Middle Palaeolithic age assigned to them. Accordingly, rather than Middle Palaeolithic quarrying debris, the heaps would constitute raw material for the manufacture of lime during the last three millennia or so (Sasson 2002).

Lime was an important element in building the traditional Levantine house (Peled 2010). Building a house started by building a lime kiln at the site (Canaan 1933). Large quantities of lime were used: mixed with sand, the lime served as mortar to bind the building stones while mixed with clayey earth, it served as plaster to be applied on walls and roof to repel atmospheric humidity (Canaan 1933). In the immediate area of the heaps discussed here around Nahal Galim, remains of some 20 lime kilns were revealed by the Archaeological Survey of Mount Carmel (Ronen and Olami 1978; Olami et al. 2003). Each kiln was fed ca. 4-5 tons of limestone fragments. The stones were burnt during 4-5 days until they became lime. Then the kiln was left to cool for 3-5 days before the lime could be removed and used. Hence every 10 days on the average, some 100 tons of limestone fragments were required, i.e. approximately 10 tons per day, to feed the kilns in the research area.

Conclusions

Middle Palaeolithic flint artifacts are abundantly scattered on the surface of Mount Carmel (Olami 1984). Some of these artifacts became naturally mingled in the limestone heaps. These intrusive finds do not denote the age of the heaps. The heaps are not of Middle Palaeolithic age, nor are they quarry debris. They were, in all likelihood, raw material for lime production during historical times.

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Fig. 1 Location map of the study area (red square) among MP burial sites.



Fig. 2 A heap of limestone fragments in Mount Carmel (photo, A. Ronen).



Fig. 3 Flint nodules knapped.



Fig. 4 Cross section of a lime kiln (from Sasson 2002).



Fig. 5 Remains of a lime kiln (from Olami et al. 2003).



Fig. 6 Area of the Nahal Galim stone heaps (circle) and location of lime kilns (squares).

A week (?) in the life of the Mousterian hunter

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Eight excavation seasons at the Mousterian site of Nahal Mahanyeem Outlet (NMO) on the banks of the Upper Jordan River offer a glimpse into the life ways of MP people during a hunting expedition in the Northern Dead Sea Rift. This open-air site, OSL dated to ca. 60ky BP, is interpreted as recording a series of short-term hunting events. The NMO horizons, with their small number of lithic artifacts, unique typological composition and evidence for task specific hunting and butchering activity fit within Binford's (1980) definition of a "task location". Many of the models suggested to describe site pattern and mobility activity, such as the foraging and logistical models, are based primarily upon theoretical consideration and ethnographic evidence. NMO gives us the opportunity to test such models based on archaeological evidence.

While still in dispute to some extent (the way archaeological questions always will be) the "large scale" questions of the Middle Palaeolithic (MP) in the Levant are now defined and data is available upon which to base answers. The chronological framework for the Levantine MP is established, the human biological and anatomical diversity is documented and we have a chronological sequence for the lithic phases of the Levantine MP. We can now turn to the higher resolution questions that NMO is uniquely suited to explore. These crucial questions concern the life-ways of the people, their subsistence strategies and diet, functionality of their tools, their specific tool kits and their hunting practices. An additional aspect of archaeological research that is in need of new data and study is that of the environmental background for human presence during the Middle and Late Pleistocene, a period for which the actual Levantine climatic conditions are very much in debate.

NMO's findings include a unique, small lithic assemblage comprising the highest percentage of tools to waste recorded in the Levant. The assemblage is characterized by many pointed elements and cutting elements. Importantly, the assemblage contains a very low percentage of other tool types such as scrapers. Refitting of several reduction sequences from the assemblage has enabled us to explore questions of lithic technology and raw material economy. The NMO findings also include excellently preserved organic material, including animal bones, both micro and macro-fauna and botanic remains (wood, seeds fruit and pollen).

NMO is dated to the late stage of the Levantine MP, contemporary to the presence of Neanderthal populations in the region at sites such as the Amud Cave and Kebara Cave. While the probability of exposing human remains at an open-air site like NMO is low, the site has great potential for exploring crucial questions regarding behavior of MP hominins at the brink of the appearance of anatomically Modern Humans. The small size of the assemblage, the unique typology of the artifacts and the extraordinary preservation of the bones, wood, fruits and seeds at NMO are but one aspect of the site's potential. We have now acquired information and data that enable us to suggest models that reconstruct the nature of the site and human behavior reflected in its layers and finds. Issues of cognitive abilities, hunting praxis and subsistence strategies, site function and group mobility all are in need of new, high resolution data that NMO can provide. Moreover, the high resolution stratigraphy and, above all, the excellent preservation of botanic and pollen remains can achieve a comprehensive picture of the Late Pleistocene environment and its impact on human diet, subsistence and survival.



Fig. 1 Location map of the NMO site.



Fig. 2 Refitted reduction sequence from Area D at NMO.







Fig. 3 Fauna of NMO: 1. Bovid skull compared to modern day skull; 2. Skull and femur of lion (panther leo); 3. Wild boar mandible; 4. Bos femur.
Evolution of learning capacity and acquired behaviors of Modern Humans from the perspective of life history and brain development

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Among primates, Modern Humans (Homo sapiens) have a unique growth pattern: a prolonged period of childhood and a rapid growth spurt in adolescence (Fig. 1). It is considered that the long childhood period evolved in order to promote brain growth and development by depressing body growth rate. In reality, brain growth is much faster than body growth and it completes at the ages of 7–10 (in weight). Once brain growth is complete, a rapid body growth (the so-called adolescent growth spurt) occurs to bring the body to adult size (Fig. 1).

The stages of human life history after birth are as follows: infancy, childhood, juvenile, adolescence, and adulthood (Table 1). When we consider the growth rate (e.g., height [cm/year]) that takes place during each of these stages, changes in growth rate are clearly associated with each stage of development (Fig. 1). Each stage also may be defined by characteristics of dentition, changes related to methods of feeding, physical and mental competencies, and maturation of the reproductive system and sexual behavior.

The unique growth pattern of humans coincides with the development of cognitive ability, behavior, and mind. Moreover, we consider not only body growth but also the brain development to be the foundations of learning capacity and acquired behaviors. Adolescence is a unique period for the body to grow, but also for brain development. As previously mentioned, the brain reaches approximately 90% of its adult size by the age of six, but the brain continues to undergo dynamic changes throughout adolescence.

The brain's axons become gradually more insulated with myelin, eventually boosting the axons' transmission speed up to a hundred times. While myelin sheathing greatly accelerates an axon's bandwidth, it also inhibits further axonal branching. The process of maturation continues throughout adolescence and is completed by mid-20s. This delayed completion heightens the flexibility of the brain and appears to be a unique human adaptation.

Adolescents lack consideration and engage in high-risk behaviors. Conventional brain studies have attributed this phenomenon to immaturity of the brain. Recent research, however, considers adolescent behavior to be positive from an evolutionary perspective. The differences in learning capacity and acquired behavior as well as creativity may be attributed to differences in brain development during the stages of adolescence between the Neanderthals and Modern Humans.

In this presentation, I will propose some possible scenarios about the life history and the brain development of the Neanderthals to find a way to verify the "learning hypothesis" that the Neanderthal-Homo sapiens replacement was the result of the difference in learning capacity between archaic and Modern humans.

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Fig. 1 Human growth pattern (height) and life stages. I: infancy; C: childhood; J: juvenile; A: adolescence; M: mature adult.

Table 1 Stages in the human life cycle.

Life stage	Approximate ages (years old)
Birth	0
Infancy	0-3
Childhood	3-7
Juvenile	7-10 (boys), 7-12 (girls)
Adolescence	10-18 (boys), 12-18 (girls)
Mature adult	18+

The Early Middle Paleolithic of Misliya Cave, Mount Carmel, Israel

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The long-collapsed Misliya Cave, Mount Carmel, Israel, located some 7 km north of Tabun Cave, contains Lower Paleolithic (Acheulo-Yabrudian) and Early Middle Paleolithic (EMP, Mousterian) layers. It is one of the rare Levantine sites in which both the Acheulo-Yabrudian and Early Mousterian are present, allowing direct comparison between the two industries. The Acheulo-Yabrudian, TL dated to ~250 ka ago, was found mainly on the lower terrace of the site. It is characterized by several technological systems including bifacial shaping; production of thin flakes from unidirectional cores and cores with one preferential flaking surface and prepared striking platform; production of large and thick, often cortical, flakes from unprepared cores. The thick flakes were used for manufacturing of handaxes and of large scrapers by Quina or semi-Quina retouch.

The EMP layers, spread on the upper terrace of the site, are between 1-3.5 m in depth and contain a series of well-defined hearths and an extremely rich lithic industry (Tabun D-type). TL dates on burnt flints suggest dates of ~250-160 ka to EMP layers. The emergence of the EMP is manifested by a technological break, marked by the disappearance of bifaces and thick-flake production technology together with the introduction of blade manufacture using laminar and Levallois production methods, and the Levallois method for point and triangular flake production. The tool-kit is dominated by various types of points and retouched blades. No significant changes in material culture were observed along the EMP sequence. The repeated construction of hearths, the abundant burnt flints and bones, and the high density of finds (ca. 3,000 lithic artifacts larger than 2.5 cm per cubic meter) suggest intensive occupation at the site and attest to the habitual use of fire. The rich faunal assemblage is overwhelmingly dominated by ungulate taxa with Mesopotamian fallow deer (Dama mesopotamica) and mountain gazelle (Gazella gazella) being the most common prey species. Bodypart analysis, age profiles and bone-surface modifications observed at this almost exclusively anthropogenic assemblage all attest to systematic ungulate hunting and 'modern' carcass transport and butchery patterns. Hunting was performed using sophisticated gear, employing a large variety of points of different forms and sizes. Phytoliths and charred vegetal remains indicate extensive use of plants and exhibit the earliest use of bedding to date. The spatial arrangement of EMP layers indicates that the site was used largely in the same way throughout the occupation. Recurrence of the same spatial pattern throughout the EMP sequence, together with high density of artifacts and bones and repeated use of fire suggest repeated visits and low residential mobility, much like in the late Mousterian sites in the region.

The sharp differences between Acheulo-Yabrudian and EMP lithic technologies indicate that the transition from the Lower to Middle Paleolithic in the Levant was rapid and may imply the arrival of a new population around 250 ka. Human remains are scarce. Their study will shed important light on the emergence of Modern Humans.

Preliminary study of the lithic assemblages from Nesher Ramla: A case of continuity and change in the Levantine Middle Paleolithic

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A recently discovered eight-meter-thick open-air sequence at Nesher Ramla (Israel) provides new evidence regarding Levantine Middle Paleolithic adaptations during most of MIS 6 and 5 (OSL dates: $167\pm11 - 78\pm6$ ka). The site is located in a karst depression formed by gravitational deformation and sagging into underground voids. During the deposition of the archaeological sequence the formation of the site was primarily shaped by a cyclic mechanism of deposition of eroded soils, water-logging and pedogenesis. Excavations at the site yielded rich lithic and faunal assemblages, combustion features, hundreds of manuports, hammerstones and anvils, and ochre. The eight-meter-thick archaeological sequence was divided into six stratigraphic units, in which several horizons and vertically distinct concentrations of lithics and bones were identified.

The long archaeological sequence at Nesher Ramla allows testing some of the models on the Levantine Middle Paleolithic technological variability, continuity and change. The 200,000 years long Levantine Mousterian sequence show a little technological diversity and is dominated by Levallois reduction strategy. During the early part of the Levantine Mousterian (250-160 ka), Levallois reduction strategy coexisted with systematic use of laminar technology, but it became the dominated formal reduction strategy during the later part of the Mousterian (160-45 ka).

Variability within the Levallois reduction strategy has long been a subject for heated debate. Some scholars see a shift from recurrent centripetal to recurrent convergent unipolar Levallois methods around 70 ka and suggest that it was associated with the arrival of the Neanderthals. Others suggest that assemblages prevailed by either of two methods are not arranged in the chronological order and rather represent group preferences within a general population and cultural continuity in the Levant.

We will present a technological analysis of the lithic assemblages from main archaeological units of Nesher Ramla and discuss their implication for the understanding of the technological continuity and change between 170-80 ka, and especially for the shift from centripetal to convergent modes of Levallois flaking.

Technological trends of the Middle to Upper Paleolithic transition at Sefunim Cave, Israel

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In his monograph about the archaeology of Sefunim Cave in Israel, Ronen (1984) reported the sequence to be transitional between the Middle and Upper Paleolithic. However, detailed technological studies of the lithic assemblages were lacking. Furthermore, studies about the large mammalian fauna, micromammals, paleoecology and geoarchaeology were also needed to place technological developments at the site into an ecological framework. Therefore, we established a joint mission between the Universities of Tübingen and Haifa to re-examine this important Levantine sequence. The aims of this project are to collect new data about unresolved issues by: 1) investigating behavioral patterns and the environment; 2) correlating changes in behavioral patterns with fluctuations in the environment; 3) analyzing mobility patterns throughout the sequence; 4) examining the possibility of population movements during the Upper Paleolithic and 5) assessing whether evidence for acculturation exists.

Sefunim Cave (also known as Iraq el-Barud) is located 2.7 km east of the Mediterranean coastline in the Carmel Mountain National Park (Fig. 1). The cave is situated at an altitude of 125 m above sea level in a steeply incised valley known as Nahal (Wadi) Sefunim. Located near the base of a massive limestone outcrop and opening to the north, this cave complex consists of three adjoining chambers and additional niches along its 60 m length and 20 m width. The front chamber contains some of the largest dripstone features known in Mount Carmel.

Stekelis (1961) dug a test excavation in 1941 and uncovered a 1.2 m sequence with an Aurignacian horizon at its base and overlying Kebaran, Natufian and Pre-Pottery Neolithic (PPN) layers. Ronen (1984) conducted spatially extensive excavations from 1965-1969 and succeeded in documenting a 2.0 m sequence starting in the Mousterian and continuing through Initial Upper Paleolithic, Levantine Aurignacian, Natufian and PPN occupations (Table 1). He also discovered prehistoric occupation on the terrace outside of the cave with Mousterian deposits overlain by PPN. Ronen pinpointed the location of the Mousterian layers to the entrance and terrace of the cave and recognized that the Upper Paleolithic layers were more extensive than the Middle Paleolithic horizons. He attributed large rockfalls at the entrance of the cave to Holocene collapse, and these likely helped preserve the archaeological deposits.

In May 2013 the authors renewed field activities at Sefunim. The first season included two weeks of fieldwork and confirmed the presence of intact stratified sediments. The excavation at the drip line covered 3 m^2 and extended to a depth of 45 cm, while a single square meter dug on the terrace reached a depth of 55 cm. Excavation at the drip line encountered the top of Ronen's Levantine Aurignacian layer 8 (Fig. 2). The new excavation unearthed sediments rich in finds, including numerous lithic artifacts and faunal remains, as well as shell beads, bone tools and ocher. In contrast to the excavation at the drip line, the terrace excavation yielded few finds, but the presence of Levallois technology allowed their attribution to the Middle Paleolithic.

Preliminary studies of the lithic materials show that our layers II-IV are characterized primarily by blade and bladelet production. Waste includes cores, core trimming elements, primary element flakes and regular

flakes. Blank production was aimed at the manufacture of narrow and elongated bladelets characteristic of the early Epi-Paleolithic. Among the microlithic tools, backed and obliquely truncated bladelets were found that are typical of the Kebaran. While the presence of several small triangles is notable, the frequency of microliths among the tools is not as high as at Epi-Paleolithic sites on the coastal plain. This may signify that a different set of activities occurred at mountain sites than on the coastal plain. Further study is underway to examine differentiation among layers II-IV and confirm whether these all of these set of layers can indeed be attributed to the early Epi-Paleolithic. While only the top of layer V was uncovered and the lithic assemblage from this unit is currently small, elements typical of the Levantine Aurignacian were noted, including carinated tools and pieces bearing intrusive flat retouch from both lateral edges.

Paralleling our study of the new material we began technological analysis of the material from Ronen's excavation. We focused on Ronen's Layer 8, which is considered to be one of a few "classic" Levantine Aurignacian occupations (Goring-Morris and Belfer-Cohen 2006). Our technological analysis confirms Aurignacian elements such as carinated scrapers/cores and pieces with Aurignacian retouch. We also found extensive evidence for blade production characterized by the débitage frontal technique, shaping of ridge blades and removal of overshots and core tablets. We hope to reconstruct the reduction sequences of blade production characterizing the Levantine Aurignacian to answer such questions: To what extent does blade production of the Levantine Aurignacian differ from the Ahmarian? (Davidzon and Goring-Morris 2003) Was it constant in character throughout the three Levantine Aurignacian layers present at the site?

Complementing the lithic studies, a comparison of the marine shell assemblages from the Upper Paleolithic and later periods illustrates certain trends. Upper Paleolithic inhabitants of Sefunim preferred small shells such as Columbella rustica and scaphopods, while Neolithic inhabitants chose larger *Glycymeris* sp. and selected a more diverse array of mollusks (Table 2). Regardless of the period, shells were perforated at a steady rate. Most Upper Paleolithic shells are small, suggesting that people brought them to the site for ornaments and not food. Shell surface preservation is poor, indicating that specimens were collected from beach deposits. The spectrum of marine shells allows us to infer that the marine ecosystem remained constant over time and is similar to today. As such, we interpret the variability in the assemblages of shells as an indication of different cultural perceptions (Bar-Yosef Mayer 2005).

Bone tools are few and mainly include fragments of perforators. While small pieces of ocher are commonly found, one exceptionally large piece of red ocher was heavily abraded. With renewed excavation and further studies underway, we expect to add significant new information about the transition from the Middle to Upper Paleolithic, as well as variability during the Upper Paleolithic.

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Fig. 1 Sefunim Cave. View of cave to the south with inset map showing site location (yellow star) 10 km south of Haifa (Photo: A. Fernandes).



Fig. 2 Sefunim Cave. Profile drawing showing stratigraphy of the 2013 excavation at the drip line of the cave, as well as location of finds and micromorphological samples. Archaeological horizon V corresponds to Ronen's Levantine Aurignacian layer 8, but see Table 1 for complete correlation.

Period	Industry	Ronen (1984)	Current work
Modern		1-4	Ι
Neolithic		5	
Neolithic		6	
Neolithic		7	
Epipaleolithic	Kebaran?		Π
Epipaleolithic	Kebaran		Ш
Epipaleolithic/UP	?		IV
Upper Paleolithic	Levantine Aurignacian	8	V
Upper Paleolithic	Levantine Aurignacian	9	
Upper Paleolithic	Levantine Aurignacian	10	
sterile	sterile	11	Not yet excavated
MP/UP	"transitional"	12	
Middle Paleolithic	Levantine Mousterian	13	

 Table 1
 Sefunim Cave. Cultural stratigraphy showing correlation of Ronen's layers with the current excavation.

Table 2 Sefunim Cave. Distribution of main types of marine shells and degree of perforation from both excavations using Ronen's stratigraphy (Note: not all shells are presented here).

		0	0 1 2	•		•	,
Period	Columbella rustica	Nassarius gibbosulus	Scaphopods	Glycymeris sp.	Total	Perforated (n)	Perforated (%)
Surface and indeterminate		1	2		3	1	33%
Neolithic and younger	4			13	31	12	39%
UP Layer	14	3	8	1	29	12	41%
MP/UP Layer		1			1	1	100%
TOTAL SHELL	18	5	10	14	64	26	41%

The Ahmarian in the context of the earlier Upper Palaeolithic in the Near East

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There is a general consensus that the Ahmarian technocomplex represents an endemic Upper Palaeolithic entity that emerged in south-western Asia. Its entrenchment in the region is apparent over a long chronological span and a wide geographic range, as is most especially apparent in the Levant. Notwithstanding diachronic and synchronic variability, its basic parameters have been widely recognized since it was first defined over 30 years ago. The defining characterization of the Ahmarian is based on certain intrinsic features as well as on the absence of hallmarks of other Upper Palaeolithic entities in the region.

Our paper focuses on the techno-typological characteristics of the Ahmarian industries from an evolutionary perspective, with specific examples from different phytogeographic settings within the Levant, in an attempt to compare and contrast the variability present within the technocomplex and in relation to other Upper Palaeolithic entities.

The Upper Palaeolithic of Manot Cave, western Galilee, Israel

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The Upper Palaeolithic of the Levant (45,000–22,000 BP) represents the full establishment of Modern Human behavior in this region following the existence of both Modern Humans and Neanderthals during the Middle Palaeolithic. The Levantine Upper Palaeolithic shares some similarities to its European counterpart but otherwise is quite different. The Levantine Upper Palaeolithic is broadly divided into three chronological stages (Initial, Early, Late), with several cultural entities. While the Initial stage is the interface between the Middle and the Upper Palaeolithic, it is the Early Upper Palaeolithic when Modern Human populations have fully established themselves in the region. The Early Upper Palaeolithic consists of two cultural entities, "Ahmarian" and "Levantine Aurignacian". The Ahmarian, dispersed throughout the Levant, is conceived as local tradition whereas the Aurignacian, constrained to few cave sites in the Mediterranean woodland region, is considered an interference of European population/s.

In this paper we focuses on the chrono-cultural sequence at Manot Cave with special emphasis on the lithic faunal as well as the human remains of the Upper Palaeolithic. Manot is a nearly-sealed, active karstic cave, located in a hilly landscape in the western Galilee, Israel. A recent excavation uncovered rich archaeological accumulations attributed mainly to the Early Upper Palaeolithic period (both Ahmarian and Aurignacian traditions) as well as a few Middle Palaeolithic, Initial Upper Palaeolithic and Epipalaeolithic remains.

Living on the edge: The earliest Modern Human settlement of the Armenian Highlands

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Aghitu-3 is the first stratified Upper Paleolithic cave site discovered in Armenia. The site is situated in the Syunik volcanic region of the Southern Caucasus and has yielded three intact Upper Paleolithic horizons. Each horizon contains archaeological finds including lithic artifacts, faunal remains and combustion features. The site is also important because of its excellent preservation of paleoecological archives such as micromammals, fish, birds, reptiles, amphibians, charcoal, pollen, non-pollen palynomorphs (NPPs) and tephras, which allow for a comprehensive interpretation of the climate and environment at the time the first Modern Humans populated the Armenian Highlands. Twelve geological horizons (GH) were identified, and correlate with seven archaeological layers (AH), as shown in Fig. 1. With dates ranging from 40-24,000 cal BP, the site of Aghitu-3 offers us a glimpse into the settlement patterns of early Modern Humans during the early and middle Upper Paleolithic of Armenia.

The layers that yielded the Upper Paleolithic material are AH VII, VI and III, while AH V and IV yielded very few artifacts. The distribution of lithic artifacts, faunal remains and charcoal is presented in Table 1. The two lower find horizons AH VII and VI dated between about 40,000 and 33,000 cal BP, whereas the upper find horizon, AH III, dates between 29,000 and 24,000 cal BP (Fig. 2).

This camp of hunters and gatherers very likely marks one of the earliest arrivals of anatomically Modern Humans into the southern Caucasus. The lithic technology is aimed at producing laminar blanks following a unidirectional logic, with bladelets predominating. The majority of these blanks are finely retouched along one lateral edge, with semi-abrupt retouch also common. While true backed elements are present, they are in the minority. Other retouched lithics such as scrapers, burins, splintered pieces and points are less frequent. The lithic raw materials include obsidian and chert, both of high quality and from a variety of sources from as far away as 250 km. The overall low number of artifacts, the low frequency of cores, and the comparably high number of retouched pieces suggest that this camp was used for short term stays rather than as a base camp.

Two awls and a broken eyed needle in AH III offer interesting perspectives on the use of bone tools and indicate that the inhabitants of Aghitu were making clothing, nets or bags. Most specimens of the faunal assemblage are mid-sized ungulates (wild sheep and wild goat) with equids also common. While evidence of carnivore activity is present in AH VII and VI, humans appear to have accumulated most of the fauna from AH III. The genetic analysis of a complete canid skull and post-cranial elements suggests an affinity to wolf, raising interesting questions about the timing of canid domestication in the Caucasus. Paleoenvironmental indicators such as micromammal remains, pollen, charcoal and sedimentology suggest a cooler climate for AH VII, but warm and humid conditions for AH VI. The climate became increasingly colder and drier with the approach of the Last Glacial Maximum, as shown by the sequence from AH V to III.

Recent research at several Middle Paleolithic sites in Armenia has been successful in creating a new framework for understanding the rise and fall of Neanderthals in Armenia, for example, at the Middle Paleolithic sites of Bagratashen-1, Hovk-1, Lusakert-1, Angeghakot-1, Kalavan-2 and Barozh-12. Thus the



well-stratified and recently excavated cave site of Aghitu-3 offers a unique perspective on the shift from Middle to Upper Paleolithic technology with the arrival of anatomically Modern Humans in the Caucasus. The 16,000 year time span represented by Aghitu-3 is particularly interesting as it allows us to investigate diachronic as well as technological dimensions of the shift from the Middle to the Upper Paleolithic in the Southern Caucasus. One of the many scientific challenges facing the research team will be the incorporation of the site into a wider regional context. Georgian sites such as Dzudzuana Cave and Ortvale Klde are of great interest for comparison. Furthermore, the Armenian site of Kalavan-1 documents the late Upper Paleolithic at the end of the last Pleniglacial (ca. 18-16,000 cal BP). Due to its unique stratification and age, Aghitu-3 will serve as the Armenian benchmark for the early and middle Upper Paleolithic. Finally, the continuing analyses will make a crucial contribution to the development of a frame of reference for the Caucasian Upper Paleolithic.

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Archaeological horizon (AH)	Ш	IV	V	VI	VII	TOTAL	%
Area excavated (m2)	40	12	12	12	4		
LITHICS							
Blanks	2408	2	6	250	94	2760	51%
Retouched tools	564	3	4	72	9	652	12%
Cores	66	-	_	3	5	74	1.4%
Angular debris (chunks)	128	-	_	17	4	149	2.8%
Small debitage (chips)	1739	-	—	32	_	1771	33%
LITHIC subtotal	4905	5	10	374	122	5416	100%
Retouch index (excluding chips)	17.8%			21.1%	7.4%		
FAUNA							
Small mammals (SC1)	12	_	1	14	1	28	2.5%
Small-medium mammals (SC2)	491	_	4	84	13	592	52%
Large-medium mammals (SC3)	422	_	1	8	9	440	39%
Large mammals (SC4)	16	_	1	1	_	18	1.6%
Fish	15	_	_	1	24	40	3.5%
Hare	4	-	—	5	1	10	0.9%
Fox	1		_	-	_	1	0.1%
Wolf	1	_	1	2	-	4	0.4%
FAUNA subtotal	962		8	115	48	1133	100%
CHARCOAL	821	5	14	227	93	1160	

 Table 1
 Distribution of lithic, faunal and charcoal finds in the archaeological horizons including data from the 2009-2013 field seasons analyzed through July, 2014.

Typo-technological analysis of the Late Middle Paleolithic bifacial industry of Qaleh Bozi Rockshelter, Central Iran

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Introduction

Iranian Middle Paleolithic is mainly known from a number of excavated and surveyed cave and rockshelter sites in the Zagros Mountains which their lithic assemblages were the basis for defining of Zagros Mousterian. An industry characterized by discoid and Levallois core methods of flake production. The Zagros Mousterian assemblages characterized by intense core reduction and tool retouch that reflected in the small size of exhausted cores and heavily retouched tools (Dibble 1984; Lindly 2005; Skinner 1965). As a result, the assemblages are rich in various types of side-scrapers such as single, double and convergent scrapers showing invasive and steep retouch on their edges.

Recent research in a cluster of Middle Paleolithic cave and rockshelter sites near Isfahan, situated between Zagros Mountains and central desert of Iran, produced lithic assemblages showing features that are new to Iranian Middle Paleolithic industries. This paper first briefly describes some results of excavations carried out in this site complex and then it presents analysis of obtained lithic assemblages from Qaleh Bozi Rockshelter that provide insights into the Middle Paleolithic lithic variability and human behavior in this transitional zone between high Zagros Mountains and Iranian central deserts.

Qaleh Bozi sites

The Qaleh Bozi sites are situated about 25 km south-southwest of Esfahan, close to the inner foothills of the Zagros range. The sites include a large rockshelter (QB 1), a large cave (QB 2) and a very small rockshelter (QB 3) located between 1750 and 1810 meters above sea level, on the southern face of Qaleh Bozi Mountain.

Surface sampling and test excavations in QB2 and QB3 in 2005 and 2008 produced diverse vertebrate remains and lithics artifacts, mostly in a fresh condition. (Biglari et al. 2009; Jaubert et al. 2010). Apart from small excavated assemblages in 2005 and 2008 seasons, majority of the Middle Paleolithic material from Qaleh Bozi 2 found in a disturbed context. Test excavation in the Qaleh Bozi 3 yielded a small, but rich Middle Paleolithic industry associated with scattered faunal remains.

Qaleh Bozi Rockshelter

Qaleh Bozi Rockshelter (QB 3) lies about 110 m to the south of the large cave of Qaleh Bozi (QB 2). The shelter faces northwest, overlooking a steep rocky slope. It is a small rockshelter, 5 m deep, 3 m wide, with 8 m^2 of interior floor space. Test units placed within a grid-coordinate system and six adjacent units (150×100cm) were excavated to a depth of 180cm. The arbitrary excavation levels grouped into three major stratigraphic units, labeled I, II, and III from top to bottom.

In total, the excavated deposits yielded near 200 lithic artifacts and about 300 bone fragments and teeth which came from stratigraphic unit II. The majority of faunal assemblage belong to medium and large mammals. The

only taxa clearly identified are small ruminants, with the presence of the teeth. The small ruminants can be the gazelle or wild caprini (sheep and goat). Despite high degree of bone fragmentation, presence of cut marks and percussion marks on some of the specimens indicate involvement of human in their accumulation.

The lithic industry

Generally, the artifacts are in a very fresh condition with some specimen showing light patination. The most abundant and locally available raw material is various types of cherts in pebble and cobble forms. These pebbles and cobbles procured from the Zayandeh-Rud River, about 1500 m to the south and southeast of the sites. It seems pebbles and cobbles were being brought to the site intact and without examination for quality.

The Qaleh Bozi 2 Rockshelter yielded a small collection of 196 artifacts. Large part of the assemblage (90.82 %) comes from excavation, and remaining pieces (9.18 %) found in backdirt pile from illegal excavation and from profile cleaning. The total weight of the assemblage is 925.5 grams. The lithic assemblage is largely composed of debris, chunks, shatters and flake fragments (60.21 %), followed by flakes and small flakes (19.25 %), tools (intact, broken and fragment) (15.32 %), and a small number of other categories such as pebble fragments. There are only three cores and a core fragment (Table 1).

The assemblage is characterized by high frequencies of tools, flakes and flake fragments. There are several core fragments and a thick core-on flake. Bifacial reduction is an important technology in the industry, however true core reduction is also used. There are few Levallois products in the assemblage. The tool group is heavily bifacial and it is mainly include bifacial tools, Mousterian points and scrapers that accompanied by lower frequencies of alternately retouched convergent tools, and other retouched pieces. The main characteristic of the tool group is the high percentage of both bifacial and unifacial points which comprise about 40 percent of all retouched tools. They are made of both flake blanks and pebbles. Typologically they can be assigned to Leaf shaped bifacial points, unifacial point, partial bifacial, bifacial scrapers, and various scraper types: single side-scraper, double side-scraper, convergent scraper-alternate retouch, Déjeté scraper and transverse scraper. There are also other tool types such as Notched flake, borer, truncation, retouched pieces.

The lithic assemblage was examined for refits. The main aims were to examine the vertical integrity of the deposits and to gain information about lithic technology and raw material use by Middle Paleolithic knappers during their ephemeral occupations in the site. As a result one conjoin group, one join group, and three associated groups were recognized. Among the refits, the most informative is a refit series composed of five pieces. It includes four pieces of flakes and other categories, of which two directly reattached to a broken core. The specimens were separated horizontally by less than 100 cm and vertically by less than 30 cm. This group suggests in situ knapping in the site.

A primary use-wear analysis was performed on three points from Middle Paleolithic layer at Institute of Prehistory and Quaternary Geology, University of Bordeaux 1 (Claude et al. 2012). The three specimens examined comprised two bifacial points and a Mousterian point from stratigraphic unit II. Use-wear traces were found on two of the tools.

The first tool examined is a foliate point, showing oblique scars and meat polishes on the distal part of the left edge which indicates its use in butchery. On the proximal part, especially on the central area, the ridges on both faces show macro-rounding and polish, contrary to the distal part, where the ridges show no traces. These traces may be the result of proximal hafting of the point. The second tool examined is a Mousterian point. The left edge shows scarring on the lower face due to the cutting of soft to medium hard material. The scars have a discontinuous distribution, are oblique, triangular and trapezoidal in morphology. Based on use-wear characteristics, two points were used in butchery, most probably for cutting meat (Claude et al. 2012).

Final remarks

Qaleh Bozi industry occupies a unique position in the Middle Paleolithic of Near East in general and Iran in particular. The industry exhibit techno-typological characteristics which in some aspects resembling Zagros Mousterian industries but also display certain features such as bifacial reduction which is not reported for Iranian Middle Paleolithic industries, nor from other Near Eastern Late Middle Paleolithic industries between Zagros and eastern Mediterranean.

The question that the industry is an inclusion from other regions such as central Asia or Arabian Peninsula or it is a local invention needs more new data from this region. The possibility of finding new sites with similar industry cannot be ruled out on the basis of the present evidence. These new finds from Qaleh Bozi indicate that the region was not culturally uniform during Middle Paleolithic as supposed before (Lindly 2005; Skinner 1965).

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Fig. 1 Bifacial tools and a point from stratigraphic unit II (arbitrary level 11 and 12), Qaleh Bozi.

Artifact category	Excavation	Backdirt and profile	Total	%
Tools	26	4	30	15.32
Flakes	20	1	21	10.7
Flakes (≤ 20mm)	18	-	18	9.18
Flake fragments	34	5	39	19.9
Cores	3	-	3	1.54
Core fragment	1	-	1	0.5
Chunks and debris	71	8	79	40.31
Cobble/pebble fragments	5	-	5	2.55
Total	178	18	196	100

Table 1 Qaleh Bozi 3 lithic assemblage composition.

The Middle to Upper Paleolithic transition in Zagros: The appearance and evolution of Baradostian in the light of new research

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The matter of Neanderthals disappearance and their replacement by Modern Humans or the transition from Middle to Upper Paleolithic is an intensely debated topic in Paleolithic archaeology and paleoanthropology of Europe and Western Asia. The emergence of Early Upper Paleolithic technologies signals significant changes in human behaviors during Oxygen Isotope Stage 3 in Western Eurasia. Despite more than two decades of intensive research, still no definitive agreement has been reached on the nature of this crucial shift or its responsible factors (biological, environmental, socio-cultural or an intertwined process of multiple factors). It is the beginning of the process through which anatomically Modern Humans dispersed widely and its traces recorded in the variable lithic and bone industries reported from several regions in Europe and Southwest Asia. For several decades, many of these lithic industries traditionally grouped under the title of Aurignacian technocomplexes which were considered as the marker of anatomically Modern Human dispersal. However, new lines of evidence and studies from involved geographical regions are essential to improve such explanatory models and hypotheses. The Zagros Mountain range in the west of Iran with its Intermountain eco-cultural niches is one of the areas that increasingly contribute to our knowledge of the transition from Middle to Upper Paleolithic in Southwestern Asia. The major part of the information on the Iranian Early Upper Paleolithic comes from the Zagros region or in other word from several cave and rockshelter sites in the Intermountain valleys of Kermanshah and Khorramabad and a few sites in Fars province in the southern Zagros (Fig. 1). The resemblance of Zagros Baradostian lithic industries with Aurignacian technocomplexes of Europe and Levant and also the hypothesis that it evolved out of underlying Zagros Mousterian engaged Baradostian as one of the potential candidates for ambiguous origin of Aurignacian. On the basis of similarities observed in Warwasi assemblages and Aurignacian technocomplex, Baradostian renamed "Zagros Aurignacian" and two main chronological phases described for it (Olszewski and Dibble 1994, 2006). The earlier of these has been classified as the Early Zagros Aurignacian, and includes a combination of Upper and Middle Paleolithic tools. Traditionally, the typo-technological continuities and discontinuities in lithic entities have been used to support the fundamental hypothesis of local evolution versus acculturation in Paleolithic literature. In Zagros, Warwasi assemblage is presented as an example of a transitional industry, which presents a sequence of industrial development from Middle Paleolithic into the Aurignacian. In addition to Warwasi, based on recent re-studies of lithic materials from 1965 excavation of Yafteh cave, the existence of two main typo-technological phases were described in the Yafteh Baradostian sequence (Bordes and Shidrang 2009) which share certain similarities with two phases of Warwasi but also have differences that all are described in this paper (Figs. 2 and 3). A series of new radiocarbon dates suggests that the Baradostian in Yafteh attributes to an age between 24,500 and 36,000 14C BP (Table 1) and a more recent results indicate a single chronological signal of approximately 33,500 14 C BP for the major part of Yafteh sequence (Otte et al. 2007, 2011). Radiocarbon estimations from main occupation of Yafteh appear to pre-date the chronological range of considerable Levantine Aurignacian sequences and overlap some of the Early Ahmarian ones (Otte et al. 2011).

This paper examines the lithic-based dominant hypothesis of continuity in Zagros through a more technology oriented view and put together all the evidence to build a broader overview of the Early Upper Paleolithic in Zagros and its industrial evolution. It also looks into the other lines of evidence of technological innovation

and new behavioral patterns such as relatively high exploitation of organic materials alongside lithic manufacturing strategies in Baradostian (Zagros Aurignacian) compared to Mousterian and emphasizes on different perspectives of change (Fig. 4). The main objective of the paper is the nature and extent of behavioral change in the beginning of the Early Upper Paleolithic in Zagros and implications for significant increase of behavioral complexity. For this purpose a critical review of existing hypotheses of Zagros Middle to Upper Paleolithic transition is provided and new data from a current technological study of rich and wellpreserved Yafteh lithic assemblages opens new perspectives on the subject. Based on this recent detailed analysis, which included both 2005-2008 assemblages of Yafteh cave test excavation, stratigraphical and other archaeological remains, there are three distinguishable cultural phase in Yafteh sequence. Also based on taphonomical analysis, we now have evidence to suggest that most parts of the Yafteh deposits and its units are well-preserved and contain reliable cultural information which contributes to a better understanding of techno-economical changes throughout the sequence. As the sequence of Yafteh leads us, we can trace the evolution of the Baradostian industries throughout its core management toward a more volumetric shape and more complex and diverse reduction sequences. Thus, incorporating the new information resulted from a current typo-technological and taphonomical study of the Yafteh cave assemblages into the existing knowledge provides us with a better reconstruction of the Baradostain sequence in the Zagros.

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Fig. 1 The location of main known Early Upper Paleolithic sites of Iran (Basemap courtesy of NASA's Visible Earth, http:// visibleearth.nasa.gov/).

Fig. 2 Baradostian bladelets (Type B); 2. Baradostian bladelets (Type A); 3. Arjeneh points (Drawings: S. Shidrang).





Fig. 4 The earliest known evidence of symbolic and relatively complex behaviors in Early Upper Paleolithic of Iran (Photos: Shidrang and Biglari).

Fig. 3 The main part of bifacial bladelet cores reduction sequence in Yafteh cave assemblages (Drawings: S. Shidrang).

Table 1 Table summarizing all 14 C dating and calibrated results from Yafteh cave (Otte et al. 2011).

Depth (from ground level)	Collected	Age	cal BP \pm 1 σ	Lab. Number
125	2005	$\textbf{24470} \pm \textbf{280}$	$\textbf{29252} \pm \textbf{374}$	Beta-206711
150	2005	$\textbf{33400} \pm \textbf{840}$	$\textbf{38300} \pm \textbf{1049}$	Beta-206712
200	1965	34800 + 2900/-4500		GX-711
201	1965	32500 + 2400/-3400		GX-710
201	1965	29410 ± 1150		SI-332
210.5	2008	$\textbf{33800} \pm \textbf{330}$	$\textbf{38629} \pm \textbf{528}$	Beta-245910
212	1965	30860 ± 3000		SI-333
213	2008	32190 ± 290	$\textbf{36755} \pm \textbf{384}$	Beta-251058
213.5	2008	$\textbf{33160} \pm \textbf{240}$	$\textbf{37879} \pm \textbf{450}$	Beta-251062
226.5	2008	$\textbf{32900} \pm \textbf{290}$	$\textbf{37584} \pm \textbf{501}$	Beta-251059
234	2008	$\textbf{33260} \pm \textbf{300}$	$\textbf{37957} \pm \textbf{473}$	Beta-251060
236	2008	$\textbf{33430} \pm \textbf{310}$	$\textbf{38118} \pm \textbf{471}$	Beta-245908
240	2005	$\textbf{35450} \pm \textbf{600}$	$\textbf{40510} \pm \textbf{672}$	Beta-205844
245	2008	$\textbf{33330} \pm \textbf{310}$	38020 ± 474	Beta-245909
250	1965	21000 ± 800		SI-336
251	2008	$\textbf{31120} \pm \textbf{240}$	$\textbf{35696} \pm \textbf{388}$	Beta-251061
258.5	2008	$\textbf{34360} \pm \textbf{340}$	$\textbf{39437} \pm \textbf{479}$	Beta-245913
260	2008	$\textbf{32770} \pm \textbf{290}$	$\textbf{37435} \pm \textbf{491}$	Beta-245907
260	1965	$38000 \pm 3400/-7500$		GX-709
266.5	2008	33520 ± 330	$\textbf{38212} \pm \textbf{495}$	Beta-245911
273	2008	$\textbf{34160} \pm \textbf{360}$	$\textbf{39220} \pm \textbf{518}$	Beta-245912
278	1965	31760 ± 3000		SI-334
280	1965	>36000		GX-708
280	1965	$34300 \pm 2100/-3500$		GX-707
285	1965	>40000		SI-335
290	1965	>35600		GX-706

DAY 3: December 2, 2014 Environmental Backgrounds for RNMH

vironmental Backgrounds for RNMH Timing of the RNMH in Europe Global Processes of RNMH

Presentation of the PaleoGeo database with Google Earth

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Paleoenvironmental studies cover various fields such as paleohydrology, geomorphology, paleooceanology, paleobiology, paleoclimatology, and chronology. It is difficult for an individual researcher to collect and compile enormous data regarding these fields. We have been compiling portal data and presenting them using a web-based geographical information system (Web-GIS) called PaleoGeo for the multidisciplinary project "Replacement of Neanderthals by Modern Humans".

The PHEIMS (Paleo-Hydrology and Environment Internet Map Server), a precursor of the PaleoGeo, was developed in the late 1990s by one of the co-authors (T. O.), using ESRI ArcView IMS as a main server software package. It contained information from papers in international journals of earth and Quarternary sciences published during the mid-1990s to 2002. The PaleoGeo is being developed to revive and update the PHEIMS. We improved the user interface and data quantity. The new system uses ESRI ArcGIS Server 10 and to reduce redundancy of the data, a relational database management system (RDBMS) is applied. Fig. 1 shows the interface of the PaleoGeo. Search results are shown on the map with red pins. These visualized metadata are indispensible for many researchers, for example, the Ostracod Metadatabase of Environmental and Geographical Attributes (Horne et al. 2011), and the Meta-database for Recent Paleolimnological Studies (Battarbee et al. 2007).

Google Earth is one of the most powerful tools providing high-resolution aerial imagery for the entire world (Visser et al. 2014; Demirci et al. 2013). Google Earth is not considered as a true GIS due to its limited spatial analytical operations (Patterson 2007). However, it has been used by many professionals and individuals since it was released in 2005 (Google 2007).

We applied this relatively recent tool for our research. First, all the collected data have to be converted to a Keyhole Markup Language (KML) file in the ArcGIS. KML is an XML-based language for defining the graphic display of spatial data in applications such as Google Earth and ArcGIS Explorer (Conroy et al. 2008; ESRI 2012). The extension of the file should be ".kmz". Second, if a user opens Google Earth and drags the file to the "Places", then the data will be shown. Fig. 2 shows the PaleoGeo database with Google Earth. Only one click on the display enables showing all the details including the journal name, information about each paper (authors, title, volume, year, and page numbers), theme, subtheme, keywords, DOI (Digital Object Identifier), and period (era). We found some advantages using Google Earth: 1) easier interface, 2) easier access, and 3) low cost. It is user-friendly and does not need a long-term training or software fee. Bird's eye view and street view are also available in the same operation tool (Fig. 3). Google Earth provides search function in its user interface; however, it does not search the whole of the uploaded data but only addresses.

The aim of the project behind the database is to reconstruct the distribution of Neanderthals and Modern Humans in time and space in relation to past climate change. We have been collecting information from almost three thousand articles of 13 journals regarding paleoenvironmental research (i.e., Boreas, Catena, Climatic Change, Earth Surface Processes and Landforms, Geomorphology, Journal of Quaternary Science, Palaeogeography, Palaeoclimatology, and Palaeoecology, Quaternary International, Quaternary Research, Quaternary Science Reviews, The Holocene, and The Journal of Geology). The topics of the articles were

classified into six themes (paleohydrology, earth surface processes and materials, paleooceanology, paleobiology, palaeoclimatology, and chronology) and 19 subthemes (hydrology, flood, fluvial, glacier, fluvial/glacier, sedimentology, soil, slope process, periglacial, peat land, eolian, sea-level, biology, vegetation, zoology, vegetation/ zoology, archaeology, climate, atmosphere, and chronology). PaleoGeo still has a very useful function, such as quick search function, in the user interface. However, it is less user-friendly comparing to Google Earth. In addition, the number of the paleoenvironmental studies is growing rapidly and we have to effectively cover them as many as possible. We plan to simplify the input data (latitude, longitude, title and DOI only) to include more publications. So far information about >7600 sites has been collected and the number is increasing. The collected data are accessible via the internet (http://neangis.csis.u-tokyo.ac.jp/paleogeo/). The KMZ file of the data which can be used with Google Earth will be open in a near future. Google Earth can be a better tool for sharing the metadata.

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Fig. 1 Interface of the PaleoGeo.



Fig. 2 Presentation of the PaleoGeo database with Google Earth.



Fig. 3 Bird's eye view and street view available on Google Earth.

Regional last glacial climate synthesis for the Eastern Mediterranean

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We present a regional climate synthesis for the Eastern Mediterranean region based on a variety of records including lake sediment core pollen and hydrologic indexes, as well as speleothem stable isotopes. We both examine spatial trends and gradients by considering all records individually and create a stacked record which is compared to the North GRIP ice core.

Before stacking, care was taken to ensure that the age models of each record were consistent. For older records that used the GISP2 the Meese-Sowers 1994 age scale (Meese et al. 1997), we updated their age models to the GICC05 model-extended chronology (Andersen et al. 2006; Rasmussen et al. 2006; Svensson et al. 2008; Wolff et al. 2010) using our recently developed function (Obrochta et al. 2014).

Results show in general good agreement with Greenland and North Atlantic climate, with generally variations corresponding to Dansgaard-Oeschger oscillations. Cool and dry conditions are common during stadials, and warm and moist conditions are observed during interstadials.

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Vegetation change in Europe during the Late Pleistocene dispersal of Modern Humans

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The spatial and temporal variation of vegetation distribution is an important factor in understanding the migration of Modern Humans during the Late Pleistocene. Geological evidence such as proxy data is spatially limited and it is difficult to reconstruct vegetation distribution. In order to do so, it is more effective to not only make use of the geological evidence but also to combine it with numerical simulations. Team B02 is trying to reproduce stadial-interstadial climate change, typically known as the Dansgaard-Oeschger events, by a GCM (General Circulation Model).

In the present study, we developed a new method to reproduce past vegetation distribution by applying past climate information from the GCM to a DGVM (Dynamical Global Vegetation Model) with a practical resolution which is comparable to scales associated with the anthropological evidence. We will show preliminary results for vegetation changes which correspond to differences between a typical interstadial and typical stadial climate. We also discuss the reliability of the obtained vegetation distribution by comparing with the paleovegetation reconstruction based on sediment cores. We also discuss the advantages and limitations of this modelling method.

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Cost surface analysis based on ecological niche probability to estimate relative rapidity of the dispersals of early Modern Humans

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Introduction

Timing and routes of the dispersal of early Modern Humans to Eurasia have actively been discussed (Petraglia et al. 2010; Mellars and French 2011; Dennel and Petraglia 2012; Bar-Yosef and Belfer-Cohen 2013; Boivin et al. 2013; Digandžic and McPherron 2013). In order to better understand the timing and process of migration from the archaeological and ecological viewpoints, the Replacement of Neanderthal by Modern Humans (RNMH) project is carrying out an interdisciplinary research involving archaeologists, geochronologists, climatologists, geomorphologists, and computer scientists (Kondo et al. 2013). The research group has developed a cyclopedic database on archaeological sites and lithic industries in Africa, Eurasia, and Oceania in 200 to 20 kya (Kondo et al. 2012a), a technique of the statistical refinement of radiocarbon dates (Omori and Sano this volume), and a new palaeoclimate model (Abe-Ouchi et al. 2013). These progresses made it possible to simulate the ecological niches of the human species through an ecological niche model (ENM), or a machine-learning model using the location of sites and environmental indices (such as surface air temperature, precipitation, and elevation) as heuristic operator (Kondo et al. 2012b). Furthermore, the ecological niche model can contribute to the estimation of the dispersal rate and optimal migration routes by means of the cost surface analysis in the following way.

Cost surface analysis

Cost surface analysis is a computer-based method to find a route that minimises the total cost of moving between two locations on an accumulated cost surface (Conolly and Lake 2006: 294). Such a route is called least-cost path. An accumulated (or cumulative) cost surface is created by a friction model, in which a friction value, or an index of moving cost, is allocated to each spatial pixel. In the conventional cost surface models (Gorenflo and Gale 1990; Tobler 1993; Van Leusen 2002; Neteler and Mitasova 2008: 381; Kondo and Seino 2010; Kondo et al. 2011), slope of terrain is usually used as friction value. At this point, we can use the inverse of the niche probability as alternative friction.

Ecological niche model

The niche probability of past human species can be calculated by ENM, under the assumption that human behavior was, particularly in prehistory, largely influenced by the environmental factors (Banks et al. 2008a, 2008b, 2013). In practice, the niche probability is calculated for each spatial pixel, based on (1) the location of known archaeological sites as occurrence data and (2) environmental factors such palaeoclimate (temperature and precipitation), palaeovegetation (biome) and palaeotopography (elevation, slope and aspect). Some ENM software packages, including MaxEnt (maximum entropy model), output the percentage of contribution for each environmental factor, and therefore it is possible to identify and evaluate environmental constraints to the geographic expansion of human populations. Based on this thought, the authors applied ENM to Palaeolithic stone tool industries in Europe and Siberia at 50–46 kya, the time period during which the first Modern Humans are presumed to have appeared in those regions, under the assumption that stone tool groups may reflect different human groups in terms of subsistence strategy. The preliminary results suggested that the population

using Emiran and related industries (Bohunician and Bachokirian) were likely to construct their niches in the geographic zones where the long-term variability of the coldest month temperature was larger than in those occupied by the population using Late Mousterian, Szeletian and Châtelperronean stone tool industries.

The study area (20°W to 160°E, 0° to 90°N) covered the most parts of Eurasia. Archaeological sites were classified into five lithic industry groups—(1) the Late Mousterian in the Iberian Peninsula at that period, and (2) the Châtelperronean in Western Europe, (3) the Szeletian in central Europe, (4) the Uluzzian in the Italian Peninsula, and (5) Emiran-related industries, including the Emiran in the Levant, the Bachokirian in the Balkans, the Bocunician in Central and Eastern Europe, and the Kara Bom culture in the Altai.

Regarding the palaeoenviromental data, ETOPO-1 was used for digital elevation model. Temperature and precipitation at 50–46 kya were temporarily approximated by the 6 kya climate model of MIROC 3.2 because they were under calculation. Palaeoclimatic variability was indexed for each topographic cell by the difference between values at 21 kya (or Last Glacial Maximum) and 0 kya (present days) of the MIROC 3.2.2.

The maximum entropy model (MaxEnt; Phillips et al. 2006) was applied for calculating the niche probability. All models show that the diachronic variability in the coldest month temperature most contributes to the model. The geometric mean of the niche probability values of two different industries were considered as the niche overlap rate. The results show that high niche overlap rates are observed in Central Europe, where the Szeletian and the Bohunician were present. If we assume that the Kara Bom industry in the Altai derived from the Emiran in the Levant, the model indicated three possible niche corridors through Central Asia.

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Fig. 1 Niche probability for the Proto-Aurignacian lithic industry group at 43/42 to 40/39 kya, in response to the cooler climate inferred from the hosing experiment.

Fig. 2 Relative accumulated cost for the Proto-Aurignacian lithic industry group at 43/42 to 40/39 kya, in response to the cooler climate inferred from the hosing experiment.



Introduction to the "PalaeoChron" Project: Chronological mapping of the Middle and early Upper Palaeolithic of Eurasia

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Recent advances in chronometric dating

A reliable chronology is crucial if we are to understand aspects of human evolutions, such as the spread of Modern Human populations from one or more core areas in Africa, the extinction of archaic human populations living in Eurasia and the time of overlap between various human groups.

The last decade has seen major advances in the application of radiocarbon and other dating methodologies focusing on "old" samples (prior to 30 ka) and therefore directly affecting the construction of Palaeolithic chronologies. These advances include the development of much better protocols for purifying samples of bone collagen using ultrafiltration, of charcoal using ABOx-SC and of shell using the CarDS method, prior to AMS 14C measurement.

Additionally, an internationally-agreed calibration curve extending to 50 ka for the conversion of radiocarbon ages to calendar ones, as well as the wider use of Bayesian statistics, are crucial advances towards high-resolution chronologies. Developments of the same scale and significance affect the application of luminescence dating on sediment and heated flint.

The "PalaeoChron" Project (2013-2018)

In 2012, our group was awarded a major European grant, "*PalaeoChron*"- *Precision dating of the Palaeolithic*, to continue and expand previous work on dating late Middle and early Upper Palaeolithic sequences across Eurasia. This work, which started in 2003 focusing originally on the British Palaeolithic, expanded between 2006-2011 to include a large number of Palaeolithic sites in west and southern Europe and the Near East.

With "PalaeoChron" we plan to expand our study area further to the east and into greater Eurasia to include sites located in Eastern Europe, Russia and Crimea, Central Asia and the Levant, the Altai and Transbaikal of Siberia, and Southeast Asia. We hope that with the wider participation of archaeologists from other regions, including East Asia, we will be able to construct a broader chronological framework and a spatio-temporal model for placing in major cultural and biological changes observed in the archaeological record over the last 100 ka.

In this talk, we will briefly discuss the aims of PalaeoChron and its sub-projects (radiocarbon dating, luminescence dating, single amino-acid dating, ZooMS) and we will present some preliminary results relevant to the replacement of Neanderthals by Modern Humans.

Radiocarbon dating the final Mousterian of Eurasia using advanced chemistry methods

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To understand the disappearance of the Neanderthals, a reliable chronology is required. This has largely eluded science thus far; despite many radiocarbon determinations being obtained from sites dating to the Middle to Upper Palaeolithic transition, our knowledge of the timing of this is opaque. The western European archaeological record constitutes the best evidence there is for the prehistoric replacement of one species of human by another, so deciphering the signals of this transition assumes importance in understanding what happened. For example, exploring the dates of the disappearance of Neanderthals and the arrival of Modern Humans might help us to understand the possibilities for overlap between the two groups, and therefore whether there was any genetic or genetic exchange between the two populations.

AMS dating material dating older than 30,000 BP is challenging, but work undertaken in Oxford over the last decade has improved the dating of material from this period. We have developed aspects of our pretreatment chemistry, particularly the purification of bone collagen using ultrafiltration and in the dating of single amino acids from bone, as well quantifying our background limits and corrections.

Within a large project funded by the NERC in the UK, we have been dating over 400 samples of bone, shell and charcoal from more than 50 key Palaeolithic sites in 10 countries. The main focus has been on sites with a succession of contexts containing lithic industries attributed to the Mousterian, Châtelperronian (both seemingly associated with Neanderthals), Uluzzian (now thought to be anatomically Modern Humans (AMH)), Aurignacian and Gravettian (associated with AMHs).

In this paper we will discuss the emerging chronology for the disappearance of the Neanderthals by presenting results from some of the key sites in France, Germany, Italy, Spain and Belgium. We use Bayesian modelling to derive posterior density estimates for the final disappearance data of Neanderthals in each geographic location we have studied and consider the results in a spatio-temporal model. We are now working on a range of sites dating to this period from sites further afield in Eurasia. We will describe also some of the latest results from this work.

Spatiotemporal pattern of the Middle to Upper Paleolithic transitional lithic industries in Europe: A new approach for reliability assessment of radiocarbon data

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Discussion based on a spatiotemporal distribution of archaeological sites requires extensive radiometric data in a database. However, it is crucial to pay attention to a lot of problematic or unreliable data compiled in the database. We developed a systematic data assessment process for the database to reveal the probable spatiotemporal pattern of lithic industries related to the Neanderthal and Modern Humans. In this presentation, we will present the new data assessment process and the spatiotemporal distribution of transitional lithic industries in Europe using the data mining of the RNMH database (Nishiaki 2012).

Recently, the accuracy in ¹⁴C dating especially against Paleolithic samples is increased by the development of the sample preparation procedures, such as ultrafiltration for bone (Bronk Ramsey et al. 2004) ABOx-stepped combustion for charcoal (Bird et al. 1999) and carbonate density separation for shell (Douka et al. 2010). With the advent of the improved preparation methods, the absolute chronologies of key archaeological sites around the world were revised rapidly. In the new data assessment, we focused on the age differences between the new and conventional pretreatments. Assuming that the ¹⁴C age from improved pretreatments has higher reliability than the ¹⁴C age from the conventional pretreatments, the reinterpretation of the low-reliability ¹⁴C age and its error is performed. To construct the data assessment process, we collected sets of "new" ¹⁴C age and "conventional" ¹⁴C age from the same sample from technical papers comparing preparation methods, and investigated the age difference and variation between pretreatments. As a result, the systematical tendencies was revealed in ultrafiltration and ABOx-SC, and then represented as data assessment formulas. By using the formulas, we can obtain the ¹⁴C age presumed to have been dated by the improved pretreatments from "conventional" ¹⁴C age. Although the error margin becomes larger than the prior, it is expected that the reliability of ¹⁴C age has increased. To evaluate the assessment process, the chronological sequences of Geißenklösterle, Fumane Cave and Campanian Ignimbrite, which had been constructed by problematic "conventional" ¹⁴C ages, were re-examined by this approach. The results shown good agreements with the recent revised data, and suggested the benefit of the process.

Applying this approach to the RNMH database, we revised the chronology of the transitional lithic industries in Europe. Our examination focused on 9 lithic industries to discuss the process of extinction of Neanderthals and expansion of Modern Humans: the final Mousterian, Szeletian, Bachokirian, Bohunician, Uluzzian, Chatelperronian, Jerzmanowician, Proto-Aurignacian and Early Aurignacian. Based on all of the data in the RNMH database, we will illustrate the spatiotemporal pattern of the traditional industries, and show the new perspective about the replacement of Neanderthal by Modern Humans.

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Replacement process of Neanderthals by Modern Humans in Europe

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Since 2010, the RNMH project has been compiling an extensive archaeological database (Neander DB), which covers the chronological period between c. 200 and 20 ka, spanning from Africa and across Europe, to Siberia, West, South and East Asia, and into Oceania (Nishiaki 2012; Sano et al. 2013). The European database contains the richest records, including a total of 737 sites, 2,154 cultural horizons, and 3,453 radiometric dates (as of July 30, 2014). In order to accurately reconstruct the process underlying the demise of Neanderthals and Modern Human dispersals, a rigorous examination of radiometric dates by advanced assessment of data reliability and Bayensian analysis was undertaken.

Although previous studies reconstructed the gradual decline of Late Mousterian sites by 28 ka (van Andel et al. 2003) or suggested the late survival of Neanderthals in southern Iberia (Finlayson et al. 2006), our examination indicates more rapid decrease of Neanderthal sites after Heinrich Event 5 (HE5). Unlike the recovery of the Late Mousterian sites after MIS4, Neanderthals seem to have never increased their population size after HE5.

During the declination process of Neanderthal populations, the first Modern Human groups represented by the Bachokirian/Bohunician industries expanded into Central Europe at c. 47 k cal BP, which coincides with abrupt warming after HE5. As the number of the Bachokirian/Bohunician industries is relatively small, their population size was probably not extremely large and it is uncertain whether or not the Bachokirian/Bohunician people further migrated into Western and Southwestern Europe. Slightly after the first Modern Human dispersal, the Uluzzian emerged in the Italian Peninsula by 45 k cal BP and the Chatelperronian at around 45 k cal BP in the Franco-Cantabrian. Then, the Proto-Aurignacian appeared in the Mediterranean region at c. 43 k cal BP and expanded the territory during short-period of time. Although the climate has dramatically changed between 45 k and 40 k cal BP due to the Dansgaard-Oeschger events, the Proto-Aurignacian Modern Humans developed their population size. In contrast, the population density of Neanderthals has extremely been reduced during this period and they became extinct at latest during HE4.

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Diffusion or progressive integration? Re-considering the widespread distributions of early UP/LSA bladelet technologies from west Asia to south Europe and from east Africa to south Asia

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Existing hypotheses for the widespread distributions of early UP bladelet technologies

The Late Pleistocene Out-of-Africa models of Homo sapiens, as variously delineated by genetic and palaeoanthropological studies, have greatly influenced interpretations of behavioral and cultural records from the Middle and Initial/Early Upper Palaeolithic periods in Eurasia. For example, several archaeologists have proposed that lithic techno-typological similarity among some of the Initial Upper Palaeolithic or "transitional" industries in the Levant (i.e., the Emiran), central Europe (i.e., the Bohunician), and the Altai (i.e., Kara Bom) can be regarded as "road-signs" of Homo sapiens groups expanding their geographic distributions from the Levant to other parts of Eurasia. Similarly, recently increasing Middle Palaeolithic (MP) records in the Arabian Peninsula have greatly contributed to discussions on the early dispersal of Homo sapiens along the "southern route". Although these two cases of archaeological interpretations remain to be attested by human fossil records, later widespread distributions of bladelet technologies during the Early Upper Palaeolithic (EUP) in western and southern Eurasia are more widely accepted as cultural phenomena associated with Homo sapiens' geographic expansion. For example, several researchers suggested a technological and chronological correspondence between assemblages under the category of the Ahmarian in the Levant and the Protoaurignacian in southern Europe. These industries have been also compared with the Baradostian in the Zagros and EUP bladelet assemblages in the Caucasus and discussed in relation to the model of Homo sapiens' dispersal along the "northern route". For researchers who accept the hypothesis of earlier dispersal indicated by the Emiran-Bohunician cultural link, the Ahmarian-Protoaurignacian connection means another dispersal event, and these multiple dispersal events are considered to represent the "stepwise" colonization of Europe by *Homo sapiens* (Hublin 2013). On the other hand, the "southern route" hypothesis has also been archaeologically examined by comparing geometric microliths and some decorative objects between late MSA/early LSA in east/south Africa and early UP in south Asia.

From a standpoint of the Out-of-Africa models, these widespread occurrences of bladelet technology have been interpreted to represent cultural diffusions from the Levant and Africa driven by population movement. More precisely, the bladelet technologies are considered to have initially occurred in limited geographic areas, i.e., the Levant and Africa, and spread afterwards in association with the dispersal of *Homo sapiens* populations. Such diffusion hypotheses have implications for learning behaviors involved in the spread of this technology because the hypotheses distinguish between core areas, where technological/cultural innovations occurred (Bar-Yosef 2007), and surrounding areas, where migrating groups from the core areas kept the same technology/ culture through social learning without further innovations although they probably faced new natural and social environments. On the other hand, Le Brun-Ricalens et al. (2009) have proposed an alternative interpretation for the widespread occurrences of bladelet assemblages in southern Europe and west Asia, suggesting the independent mosaic appearance of bladelet technologies in various areas and their progressive integrations through time. Instead of an innovation center, this view assumes indigenous technological developments in multiple locations that were progressively connected with each other possibly through a technological transfer. This paper considers these alternative interpretations for the wide geographic occurrences of EUP bladelet assemblages in western/southern Eurasia and east Africa by introducing two relevant archaeological records investigated by Japanese expeditions from The University of Tokyo and Nagoya University.

Wadi Kharar 16R and Mtongwe: Japanese investigations of early UP/LSA bladelet industries in Syria and Kenya

An EUP site of Wadi Kharar 16R, located in the middle Euphrates, was discovered in archaeological survey conducted by the Syria-Japan joint project between 2008 and 2011 (Nishiaki et al. 2012). We recorded more than 350 locations where artifacts or features (mostly Bronze Age tomb mounds) were found on the surface. The openair site of 16R is located on the left bank of Wadi Kharar. The site is comprised of two concentrations of lithics on the sloping surface; a concentration in Area 1 measures ca. 10 m x 10 m and another in Area 2 is ca. 10 m x 5 m. Techno-typological characteristics of the chipped-stones excavated from this site are similar to those of Ksar Akil Phase 4, which is typologically characterized by higher proportions of end-scrapers, particularly simple-end scrapers. El-Wad points and retouched blades/bladelets are common and tend to be made on blanks with straight or curved, rather than twisted, profiles. Burins are predominantly dihedral types. Carinated pieces are present but infrequent. Technologically, cores are dominated by single platform bladelet varieties, and blades/bladelets have straight or curved profiles instead of twisted ones. Bladelets were produced from multiple strategies. Notably, these techno-typological characteristics of Ksar Akil Phase 4 have recently been suggested to show strong similarity to "the Early Ahmarian of the marginal zone" (Williams and Bergman 2010: 144) despite its former categorization to the "Levantine Aurignacian".

A Stone Age site of Mtongwe is located near the Kenyan coast, ca. 4 km south to Mombasa. It is an open-air site-complex, where ca. 70 sites have been discovered in an area of ca. 800 m x 300 m on the marine terrace that was formed on the Jurassic shale covered by 30 m-thick Pleistocene deposits. The investigations of site started in 1975 as part of Nagoya University East African Archaeological Prehistoric Research, followed by seven seasons of fieldwork until 1989. The results of the excavations have been published in a series of reports (Omi 1977, 1980, 1982, 1984, 1986, 1988, 1991) although they have been rarely cited in the archaeological literature on African MSA/LSA (except for Tryon and Faith 2013). The investigators defined three different lithic industries on the basis of techno-typological features of the excavated lithic assemblages and their stratigraphic sequences. The first industry, characterized by handaxes, large flakes, and side scrapers, has been defined by assemblages from the lowest gravel layers immediately above the bedrock. The above, second industry has been defined by lithic assemblages including small bifaces, Levallois cores/flakes, and discoidal cores from upper sand-silt deposits. The third industry, relevant to this paper, includes lithic assemblages from red sand deposits that cover the top of the marine terrace where the site is located, and it is notably characterized by the occurrences of Levallois debitage, backed bladelets, and geometric microliths made on bladelets detached from single-platform prismatic cores. The proposed association of Levallois and bladelet products in the same assemblage is shown by piece-plotted ltihic distributions in four cultural layers. On the basis of such spatial/stratigraphic analyses, the investigators identified three stratified sub-groups that show gradual increase in the proportions of microlithic components as opposed to the Levallois debitage.

Drawing on the above new and little known data, the paper discusses issues on the timing and the process for the emergence of bladelet technologies in the Levant and East Africa. The discussions also include their implications for the existing hypotheses for the widespread occurrences of bladelet technologies in southern Europe and south Asia.

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Fig. 1 Chipped stones (retouched tools) from an EUP site of Wadi Kharar 16R in the middle Euphrates, northern Syria.



Fig. 2 Geometric microliths from a late MSA/early LSA site at Mtongwe, east Kenya.

Neanderthals and Modern Humans in the Indus Valley (Sindh, Pakistan): The Middle and Late Palaeolithic of a forgotten region of the Indian Subcontinent

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This paper describes and discusses the Middle and Late (Upper) Palaeolithic sites of Sindh (Pakistan), a region of the Indian Subcontinent whose early prehistory, except for the Bronze Age Indus Civilization, has never been taken into great consideration by most archaeologists.

Sindh, and the Indus Valley in general, are territories of basic importance for understanding the spread of both Neanderthals and first Modern Humans towards south-east Asia. Although some authors suggested that the first Modern Humans moved along the northern coast of the Arabian Sea, crossing both present Las Bela (Balochistan) and Lower Sindh on their way to India, no evidence of their passage has so far been recorded.

Most of the Middle Palaeolithic industries and tools so far recorded from the above regions come from the almost unpublished geological surveys made in the 1970's by Professor A.R. Khan in Lower Sindh, and the brief visits by B. Allchin in Upper Sindh. More discoveries were made during the last 30 years mainly at Ongar, near Hyderabad (Lower Sindh), and in the Rohri Hills, near Sukkur (Upper Sindh), by the Italian Archaeological Mission.

The presence of characteristic Levallois Mousterian assemblages at Ongar (Lower Sindh), and other sites along the southwestern bank of the Indus River, opens new perspectives for the study of the dispersal of Middle Palaeolithic Neanderthals, whose south-easternmost spread has systematically been neglected by most authors.

Although the presence of typical Levallois Mousterian assemblages has been recorded from Iran, Afghanistan, Uzbekistan, and former Soviet Central Asia in general, evidence of the above complexes in the Indian Subcontinent is very poor. In effect the occurrence of typical Levallois discoid cores, flakes, blades, points, Mousterian scrapers and one Mousterian point at Ongar seem to mark the south-easternmost distribution of this cultural aspect, which does not characterize the Middle Palaeolithic of the Indian Subcontinent, given that this latter is mainly characterized by unretouched flake assemblages and scrapers. Nevertheless, Levallois points and flakes have already been described as one minor component of the so-called "Late Soan" complexes of Punjab farther north along the same bank of the Indus.

Unfortunately, all the Levallois Mousterian assemblages so far recorded from Lower Sindh can be attributed to the Middle Palaeolithic only on the basis of their typological and technological characteristics. In fact they have been collected as surface find spots without associated organic material suitable for absolute dating.

Even more complex is the definition of the earliest Late (Upper) Palaeolithic assemblages in the study region. In contrast with what previously suggested, Late (Upper) Palaeolithic sites are quite common in some areas of Lower Sindh, among which are the Mulri Hills (Karachi) and Jhimpir (Thatta). The assemblages from these sites are characterised by subconical cores, bladelets, lunates of different shape and size, and, in a few cases, a high percentage of Burins. Given their typological characteristics they seem to belong to quite an advanced stage in the development of the Late (Upper) Palaeolithic period.
The situation in Upper Sindh is quite different. The flat limestone terraces of the Rohri Hill yielded evidence of an impressive number of Late (Upper) Palaeolithic flint workshops, characterised by subconical bladelet and bladelet-like flakelet cores, and millions of debitage products. A similar situation has been recorded also from Ongar, even though most of the workshops from these hills have been devastated by recent industrial limestone mining.

To conclude: Sindh is an extremely important country for the study of the Palaeolithic of the Indian Subcontinent and its related territories. It is unfortunate that, due to many factors, our knowledge of such an important territory is far too poor.

New insight into the end of the Middle Palaeolithic in Central Asia

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Central Asia has become a focal region for investigating varied processes of the replacement of Neanderthals by Modern Humans. These processes might have been more complicated than in West Eurasia, involving at least one other hominin group (Denisovans). Recent multidisciplinary research in the Altai Mountains of eastern Central Asia has revealed the occurrence of at least three different Middle Paleolithic lithic industries (Denisova, Kara-Bom, and Sibiryachikha), likely maintained by different hominin populations (Derevianko et al. 2013). Similarly, in western Central Asia, apparently different industries (Obi Rahmat and Teshik Tash) are known in the Middle Palaeolithic (Derevianko 2010). Fossil records also indicate the possible presence of at least two different hominin groups: Neanderthals (Teshik Tash) and populations displaying mixed traces of anatomically Modern Humans and Neanderthals (Obi Rahmat; Viola et al. 2004; Glantz et al. 2008).

To interpret these findings in relation to the replacement of indigenous populations by the presumed incoming Modern Humans, it is essential to establish a rigorously controlled chronological framework to which particular sets of lithic industries and fossil records are assigned. However, reliable radiometric dates are available only at limited sites (e.g., Denisova Cave and Obi Rahmat). To develop this framework, a larger array of dates from securely stratified contexts is clearly needed.

Our prehistoric research at Anghilak Cave, southern Uzbekistan, aimed to provide new data on its Middle Palaeolithic occupations, thereby contributing to construction of an adequate chronological framework. Located approximately 50 km southwest of Samarkand, the site was previously excavated by an Uzbek-American team between 2002 and 2004. A non-diagnostic human metatarsal was recovered in association with Mousterian lithic assemblages from contexts dated to ca. 42–32 ka (Beeton et al. 2014), a rather late date for the Middle Palaeolithic. Our fieldwork at this cave in 2013 and 2014 consisted of stratigraphic sampling of the archaeological and environmental materials as well as radiocarbon dating the Middle Palaeolithic deposits. Preliminary results addressed in this paper indicate that the Middle Palaeolithic occupations of this cave ended earlier than previously reported. Furthermore, the recovered lithic assemblages differ from contemporaneous assemblages from Obi Rahmat, the site with the best Middle Palaeolithic stratigraphic sequence in Uzbekistan, suggesting the co-occurrence of different Mousterian industrial facies in western Central Asia.

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Global Processes of RNMH

The exploitation and adaptation in the Asian Arctic and Paleolithic in the Baikal Siberia

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The exploitation and adaptation in the Arctic zone by Modern Human is one of the significance issues of human history. Recent studies in the Arctic area demonstrated that human activities in the polar regions of 70°N is traced back to 40,000 years old (Pitluko et al. 2012; Питулько и Павлова 2010). However, it is still not clear their origin and techno-cultural basis enabled human group to adapt to the Arctic environment. In order to explore the origin of the pioneers of the first, it is necessary to clarify Early Upper Paleolithic populations in southern Siberia and their technological basement.

In this report, we would like to present the key-points to consider the dispersal and adaptation behavior by Modern Human in the MIS3, based on the results of our joint researches focused on the transition period between Middle to Upper Paleolithic in the Baikal Siberia. The Middle Paleolithic in Eastern Siberia had been characterized original characteristics without typical levallois reduction technique. And Upper Paleolithic industries, has evolved technically through the Middle to Upper Paleolithic transition subsequent spread from Baikal Siberia to northern Eurasia, including the Arctic zone. Technological characteristics of lithic industries in the Middle to Upper Paleolithic transition period characterized by the emergence of systematic microblade reduction. With this new innovation, Modern human has become successful development and adaptation to the new living environment.

We have continued to explore lithic industries of data MIS3 in Baikal Siberia as the Japanese-Russian joint research from 2005. Through this joint research, We were able to provide cultural sequence from Middle to Upper Paleolithic accompanied by faunal remains beside of the Angara River. In Borl'shoi-Nalin 1 site, one of the survey sites in this river basin, was discovered remains of long-term human activity in the cut bank wall and as beach deposits in the modern floodplain.

Bones and Charcoals on the cultural layer from excavation area have been direct-dated between 28,000-31,000 yrBP and 40,000-41,000 yrBP. It has the potential to be confirmed cultural layer to continue more lower part of deposit. From the results of excavation from Bol'shoi-Nalin 1 site, suggest that the lithic industries stable associated with microlithic, had widely spread around of this area in the second stage of MIS3.

The lithic industry of the Early Upper Paleolithic in Siberia, are known different technological traditions. These technological diversity of lithic industries represents the reflection of the diversity of the human groups at that time. Also, the characteristics seen on their cultural-technological traditions and of their artworks prospect us that there had the immigrants from Western Siberia and Russia plain, which means the human evolution of this area was unilineal one. Therefore, we could assume that there were various and intricate human evolution stream in Eastern Siberia Area.

We could say that Middle to Upper Paleolithic transition in Eastern Siberia provide us the very valuable materials from which we can see broadness of the Anatomical human being and their culture in this area, and also the diversity of these formation process. As a turning point in the development of the Arctic area, human

groups could expand their activity spaces dramatically even further more to the new continent.

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Inferring possible contacts between Denisovan and some ancestors of modern East Eurasians

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Study of human populations on Japanese Archipelago

Japanese Archipelago stretches over 4000 km from north to south, and is homeland of three human populations; Ainus, Main-islanders, and Ryukyuans. Origins of these people have been studied for long time. Standard theory based on craniofacial data is "dual structure model". According to this model, first migrants to Japanese Archipelago came from somewhere in Southeast Asia in Upper Paleolithic age, who were ancestors of Jomon people. Second wave of migration took place later in Yavoi period (3000 BP to 1700 BP), and people came in this time from Northeast Asia. Indigenous Jomon people and new migrants in and after Yayoi period gradually mixed with each other. This model provides reasonable explanation for morphological similarity between Ainu people of Hokkaido, northernmost main island of Japanese Archipelago, and Ryukyuan people in Southwest Archipelago, despite of large geographical distance. Japanese Archipelago Human Population Genetics Consortium (2012) determined genome-wide 0.9 million SNPs for Ainus and Ryukyuans, and compared these with existing data sets. This was first report of these genome-wide SNP data, and the dual structure model was essentially confirmed. We also examined nuclear genome sequences of 3,000 year-old Jomon people whose remains were found from Sanganji Shell Mound (Fukushima Prefectural Museum 1988), using DNA extracted by Kanzawa-Kiriyama et al. (2013) for mitochondrial haplotype analyses (Kanzawa-Kiriyama et al. unpublished). We found that Jomon people were very different from modern East Eurasians (Li et al. 2008; The 1000 Genome Project Consortium 2012), and they are probably basal to all presentday East Eurasians. Furthermore, some gene flow from Denisovan genome (Reich et al. 2010; Meyer et al. 2012) to Jomon ancestors was suspected through statistical analyses as well as that from Neandelthal genome (Green et al. 2010).

Study of Negrito populations on South East Asia

Negritos distributed in Philippines Islands, Malay Peninsula, and Andaman Islands are considered to be remnants of early human migrations to Sundaland. Jinam et al. (2012) determined mitochondrial genome sequences for 86 human individuals including Malaysian Negritos, and conducted phylogenetic analysis. They also reanalyzed genomewide SNP data of people in South East Asia reported by HUGO Pan-Asian SNP Consortium (2009). We found that Malaysian and Philippine Negritos were quite different from other South East Asian populations. We proceeded to analyze close to one million genomewide SNP data of Malaysian, Philippine, and Andaman Negritos, and found some similarity among them. When we compared these data with Denisovan genome data, Philippine Aeta Negritos of Luzon Island showed higher gene flow from Denisovans than Mamanwa of Mindanao Island. This finding further strengthens hypothesis that Denisovan people admixed with early migrants from Africa probably somewhere in Sundaland.

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DAY 5: December 4, 2014 Learning Strategies and Cultural Evolution

Lives to learn? The biology and culture of Neanderthal and early Modern Human learning behaviours

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The human brain is organized entirely different from that of any other primate, implying significant disparity in cognitive abilities. The human brain also seems to be more sensitive to evolutionary changes, such as mutations, which could have affected large parts of our brains during our evolutionary history. In addition, human lifehistories differ much from those of any other primate. Here it will be discussed, first, whether or not and to which degree and extent such modern-day observations can be transferred back into the past and – second – what these observations imply for early hominin learning behaviours. The implications for the reconstruction of past lifeways will be considered and compared with the Middle Stone Age (MSA) and Middle Palaeolithic (MP) archaeological records. Special focus will be on data on land-use strategies, regional cultural variation (RCV) and tool production and standardization. Similarities and differences between these records and their implications for understanding possible differences in the modes of learning of Neanderthals and early Modern Humans will be evaluated.

TTT: Tradition, (archaeological) taxonomy and (cultural) transmission

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Our perception of the prehistoric past is formulated by material culture taxonomies. These taxonomies originate through processes of archaeological exploration. Because the taxonomies are not natural constructs, they are based on particular circumstances, specific phenomena, or loosely defined, broad criteria mixing chronology, geography, techno-typology or any of their combinations. 'Initial Upper Paleolithic', 'Mousterian of the Acheulian Tradition', 'The Ahmarian' are examples of such fluid taxonomies. Therefore, there is an inherent flaw in the endeavors to interpret data within such a framework, culminating in self-fulfilling prophecies.

How can archaeologists untie this Gordian knot? A first step has already been taken – prehistorians do not speak of cultures but of different scales of the archaeological phenomena (for example, techno-complexes), i.e., they adhere more closely to the factual record, attempting to minimize the broad (and often vague) connotations to definitions of extant 'cultures'. Another caveat to bear in mind is that there is a discrepancy between the individual human time frame, within which behavioral decisions are made, and the evolutionary time scale of archaeological taxonomies, which time-averages many such episodes of decision-making.

With these epistemological difficulties in mind, we explore in this paper the relationship between behavioral processes ("knowledge transmission") and their long-term outcomes, among which is the formation of prehistoric "traditions", trying to identify their respective imprints within the prehistoric record.

Cultural transmission in the Pleistocene: Studying Neanderthal-Modern Human contact in Central Europe during OIS3

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If we want to differentiate among the many hypotheses for why anatomically Modern Humans from Africa outcompeted and replaced evolutionary relatives in Eurasia such as the Neanderthals, it is necessary to identify the geographical and adaptive contexts in which the contact between these different hominins produced different results. If the Modern Humans immediately replaced Neanderthals in one context but in another context remained in competition with Neanderthals or influenced Neanderthal cultural behavior for a period of time, the comparison of the behavioral details between these two contexts should highlight what gave Modern Humans the greater advantage. The comparison of the archaeological records of the Middle to Upper Paleolithic (MP-UP) transition between Western Europe and Central Europe could do exactly this. For instance, the transition began at least 5 ka earlier in the Middle Danube of Central Europe than in Western Europe (Müller et al. 2011) and produced a greater diversity of industrial types, with two "transitional" industries (the Bohunician and the Szeletian) rather than one, as with the Châtelperronian in France and the Uluzzian in Italy. Yet despite their early appearance, the two "transitional" industries of Central Europe did not spread as widely or last as long as the subsequent Aurignacian. Understanding why the latter industry went "viral" across western Eurasia while the former industries did not will help us understand why Modern Humans survived the Pleistocene and our evolutionary relatives did not.

The present paper argues that studying the cultural transmission processes involved in the MP-UP transition in Central vs. Western Europe is critical to understanding why Modern Humans were able to replace Neanderthals. Yet such a study will only make progress if archaeologists are able to analyze lithic assemblages (and other material culture records as well) using methods designed from first principles to fit the question, i.e., to be sensitive to cultural transmission processes (*sensu* Boyd and Richerson 1985) according to applicable middle-range theory predictions for how specific material culture production behaviors are learnable at different degrees of social intimacy (Tostevin 2007, 2012). Instead of studying traditional retouch typological categories or chaîne opératoire-defined industries (what Shea 2014 calls <u>na</u>med <u>s</u>tone <u>tool industries</u> or "NASTIES"), the approach advocated here produces quantitative measures of similarity vs. dissimilarity between assemblages using variables that have empirically-verifiable relationships to the social transmission of technical knowledge, i.e., the learning process itself.

The present paper makes the case for how this Behavioral Approach to Cultural Transmission (BACT) can improve our study of the Middle to Upper Paleolithic transition. It does this through a comparison of the respective abilities of the BACT method vs. the traditional approach to Paleolithic systematics to test *scientifically* two hypotheses concerning the role of cultural transmission processes during the MP-UP transition in Central Europe. There are currently two alternative hypotheses for the similarity in the lithic artifacts from industries attributed to the Bohunician in Central Europe with those of the Initial Upper Paleolithic (IUP) assemblages of the Levant. In the first hypothesis, Tostevin (2003a, 2003b, 2012) applied the attribute analysis tools of the BACT method to 19 assemblages in the Levant, Central Europe, and Eastern Europe to test the continuity vs. discontinuity in blank production behaviors and tool kit morphologies between 60 and 30 ka 14C BP. In each region, the pattern of change is marked by an identical suite of flintknapping behaviors which had no precedent in any of the three regions. The chronogeographic

pattern of this data, labeled the "Bohunician Behavioral Package (BBP)", is consistent with the predictions of a cultural transmission event from the Levant, through Southeastern Europe, and ending in Central and Eastern Europe. The second hypothesis is Zilhão's (2006) suggestion that the similarities between the European Bohunician and Levantine IUP assemblages are coincidental and that the Bohunician represents a cultural continuity across the MP-UP transition. Using TL dates, artifact illustrations, and the *chaîne opératoire* descriptions of the assemblages from Piekary IIa, Poland (Sitlivy et al. 1999; Valladas et al. 2003), Zilhão concludes that the southern Polish assemblages represent "the *in-situ* development of volumetric Upper Paleolithic methods of blade debitage out of Levallois flake-based technologies" (2006: 187,189) and thus are geographically more parsimonious candidates for antecedents of the Bohunician in the Middle Danube Basin than the IUP of the Levant.

The present study contrasts how the BACT and traditional Paleolithic systematics evaluate these two hypotheses. For the use of the BACT method for testing Zilhão's hypothesis, the paper presents Tostevin's attribute analysis of the artifacts from Piekary IIa Layers 6, 7a, 7b, and 7c from the excavations conducted from 1998 through the early 2000s (trenches XX and XXII; Sitlivy et al. 2008). Using measures of similarity vs. dissimilarity in blank production behaviors and tool kit morphologies between the Piekary IIa assemblages and the BBP assemblages published to date, the results of the chronological pair-wise comparisons between these assemblages are compared to the predictions from Zilhão's hypothesis and those of the BBP hypothesis. For the use of traditional Paleolithic systematics to test the two competing hypotheses, the paper evaluates the arguments and data presented in Zilhão (2006) and Sitlivy et al. (2008). The successful design of future studies of cultural transmission in the Pleistocene are discussed in light of the advantages and disadvantages revealed through the methodological comparison.

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Transculturation versus acculturation: A clarification

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Several models have been proposed to explain processes underlying the transition between different technocultural assemblages in prehistoric archaeology. These 'transitions' either represent phenomena of 'gradualism' connected to *in situ* evolution or 'diffusionism' by various 'acculturation' processes prone to external influences (*direct loans*) and necessarily implicating long-distance migrations of populations. Following a review of the original formulation of these two processes, an alternative paradigm is proposed – 'transculturation'. Borrowed from ethnologists and introduced by F. Ortiz in 1940, this process is characterised by the integration (through indigenous re-interpretation) of external influences via *indirect loans* derived from intimate interpersonal contacts. In the sense of the term employed here, *transculturation* can take several different forms (imitation, assimilation, hybridisation, re-interpretation) that are better suited to accounting for the diverse transformations evident in the archaeological record. Contrarily to acculturation which imposes new (foreign) manners of doing things, *transculturation* reinvests the people hidden behind each techno-culture as the primary agents of their own transformation in that they may or may not be open to the diffusion of certain external ideas and have the possibility of re-interpreting them rather then suffering them.

Toward an understanding of learning strategy in the Upper Paleolithic: A case study in Hokkaido, Northern Japan

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Introduction

The learning behaviors of Paleolithic hominins are currently one of the key questions in archaeological and paleoanthropological research, in relation to development of the chaîne opératoire approach in the lithic technological studies. Since the 1990's, much attention has been focused on the skill learning behaviors of lithic production at the Upper Paleolithic sites in Europe, in order to reveal the technological and social relationship between experts and novices in lithic knappers (e.g. Pigeot et al. 1990). Recently I have demonstrated that the various learning behaviors for acquiring skill relevant to lithic production, based on the analyses of numerous obsidian refitted artifacts, were conducted at the Upper Paleolithic sites in Northern Japan (Takakura 2013).

Importantly these researches have enabled us to know how we can elucidate skill learning behaviors from the archaeological record empirically, including meaningful applications of "expert", "novice", "instruction", "exercise", "pedagogic demonstration" and "trial and error" as a means of examining variability in the technical skill levels among the lithic refitted artifacts. Although the detailed behavioral reconstructions relevant to the skill acquisition in the respective Paleolithic sites have been addressed, prehistoric archaeologists still understand little about how the learning behaviors in the past were actually related to the behavioral system of the prehistoric hunter-gatherers such as mobility, territoriality, subsistence, settlement, and regional interaction. To emphasize the behavioral and social contexts of lithic skill learning processes may lead in productive directions because such an approach can provide us with important insights into situational and institutional variability of learning behaviors in a given society.

The purpose of this paper is to show a case study on the skill learning strategies of the lithic knappers through comparative analysis of the late Upper Paleolithic assemblages in Hokkaido, Northern Japan. In this paper, I consider this issue to integrate data about the learning behaviors for blade production and the updated knowledge about inter-assemblage variability reflecting the overall behavioral system.

Learning behaviors and blade production in the late Upper Paleolithic

I focus on some of the microblade industries with the Hirosato type microblade cores from the Kamishirataki 2 (concentration Sb-9), Nittou, Takase, Ankaritou 7 sites, because these industries represent very specific technological features. Technologically identical blade and microblade reduction sequences are seen in these sites. Large chunks of debris were commonly used as raw material of stone artifacts. Discovered formal and long blades (from almost 10 cm up to 30 cm in length) were subsequently detached with careful preparation and several rejuvenation stages. We can often see rubbing on the pecked platform, presumably with the aid of abrasives. Such blades were generally used as blanks of end-scrapers, side-scrapers, gravers, and the Hirosato type microbalde cores. These industries belong to the late Upper Paleolithic according to the techno-typological perspective (Nakazawa et al. 2005).

The intensive manufacture of formal and long blades from blade cores was exclusively seen in the Kamishirataki

2 site. Based on the analysis of technological characteristics, I suggested that four refitted sets relevant to the manufacture of large blades from concentration Sb-9 at the Kamishirataki 2 site were produced by the highly skilled knappers. It is of interest to note that many of the blades detached from the blade cores in these sets were abandoned at concentration Sb-9 unlike the other numerous refitted sets in Shirataki. One conclusion that can be drawn from this is that the expert knappers were not aiming at producing good blades for immediate use, but rather instructing beginners. These materials can be interpreted as "academic cores" (Takakura 2013).

On the other hand, at the Nittou, Takase, and Ankaritou 7 sites, the manufacture of microblades and several rejuvenations of stone tools such as end-scrapers and gravers were only carried out. Stone tools of these sites are dominated by numerous end-scrapers, side-scrapers, gravers, and graver spalls. In addition, hearths and dense of charcoals around the lithic concentrations were exclusively recovered from the Nittou and Ankaritou 7 sites. Consequently it is difficult to recognize traces of learning behaviors for blade production from these sites, although various data in relation to daily and domestic activities can be apparently acquired.

Conclusion

The Kamishirataki 2 site is located near a huge outcrop of obsidian, whereas the Nittou, Takase, and Ankaritou 7 sites are located far from the raw material sources (from almost 30 km up to 180 km in distance). These situations might lead to a difference in place and opportunity of the blade production and the learning behaviors in the microblade industries with the Hirisato type microblade cores. The availability of raw materials probably permitted such pedagogic demonstration by expert knappers.

The available data show that the concentration Sb-9 at the Kamishirataki 2 site was used specifically for the manufacture of blades and bifacial points, and does not contain traces of daily and domestic activities such as maintenance of stone tools. It is apparent that the formation of this concentration was related to the specific activities by knappers responsible for the manufacture of stone tools. This result suggests that the learning behaviors for blade production at the Kamishirataki 2 site were conducted by specific members away from the context of daily activities.

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Fig. 1 Map showing the sites yielding the industries with the Hirosato type microblade cores.

Table 1	List o	f the	number	of	stone	artifacts	in	the	industries	with	the	Hirosato	type
microbla	de cor	es.											

	Sb-9, Kamishirataki 2	Nittou	Takase	Ankaritou 7
End-scraper	15	3	15	31
Side-scraper	12	3	11	7
Graver	3	2	28	57
Spall	4	4	65	247
Drill	0	0	6	9
Bifacial point	0	0	5	3
Flake adze	0	0	4	6
Bifacial axe	0	0	0	1
Blade	279	6	65	82
Microblade	69	257	245	193
Blade core	0	0	1	0
Microblade core	12	3	8	9
Flake	1340	1067	25	1426
Hammerstone	0	0	0	3
Grindstone	0	0	0	1

Innovation, processes of social learning and modes of cultural transmission amongst the Chabu adolescent foragerfarmers of Ethiopia

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Innovation, as an element of behavioral plasticity, has been hypothesized to enhance the fitness and survivability of individuals, while overall increasing the diversity of cultural traits overtime. Based upon an earlier study of innovations and their transmission and acquisition amongst Aka forager adolescents of central Africa, this study examines the same topic among Chabu adolescents of southwestern Ethiopia, a forager-farming society. Research with the Aka foragers questioned several evolutionary predictions about who should innovate and how innovations should be transmitted (i.e. adolescents, males in particular, should be more innovative than children and adults; innovations should spread by horizontal transmission and; adolescents should pay particular attention to prestigious, "successful" peers). In-depth and structured interviews, informal observations and systematic ranking and sorting techniques with fourteen Chabu adolescents and eight adults were utilized in this study. Results indicate that as with the Aka data: 1) cultural terms specific to innovation existed; 2) innovations and innovators were easily identified by adolescents; 3) innovators actively sought out individuals who exhibited pro-social qualities and were "good teachers" and; 4) adults were more often identified by the adolescents to be innovators. One result was inconsistent with the Aka study: Chabu adult females were more likely to be identified as innovators than were adult males.

Cognition and cultural niche construction among Neanderthals and Modern Humans

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This paper summarizes recent research on social learning in contemporary hunter-gatherers and how these data may provide insights into why Modern Humans replaced Neanderthals. First, the question as to whether or not two cognitive mechanisms hypothesized to be essential to human cultural evolution—teaching and overimitation—exist among contemporary foragers is considered. Second, an overview of the culturally constructed niches of social learning in contemporary foragers is provided. The interactions between the cognitive mechanisms and the culturally constructed niches are hypothesized to contribute to rapid, high fidelity, and innovative social learning. Finally, comparisons between the culturally constructed niches of Neanderthals and Modern Humans are utilized to explain Neanderthal replacement by Modern Humans.

Theoretical and ethnographic studies on play and learning behaviors: The case of hunter-gatherer children in the forest

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Play and brain science

Play activities are phenomena that are widely observed both among humans and animals. It is possible to regard them as behaviors acquired in the process of evolution. It is also important to analyze and understand play behaviors in the aspect of brain science. Recent brain science argues the relationships between categories of play behaviors and particular parts of the brain (for example, the positive correlation between the frequency of social play and the size of the cerebellum among several species of mammals). Also, it is pointed out that some neurotransmitters and receptors are related with particular categories of play (for example, the relationship between the μ -opioid receptor and the social play) (Nakagawa 2012).

The studies on play conducted by sociologists and cultural anthropologists have developed the theory of universality and cultural particularity through the analyses of diverse play of humans (Caillois 1957; Kamei ed. 2009). This theory can be reinforced by the brain science on play. Though there exist researches that consider play as any behaviors that are marked by meta-communication of "*this is play*" (Bateson 1972), these kinds of phenomena also can be examined in the viewpoint of brain science.

Culture and play

Play is often regarded as one of subcategories of human culture in general. However, it can be considered as more essential factors for culture. I pointed out three essential and universal aspects of play referring to classical studies on it: (1) play is free; (2) play is done in limited time and space; (3) play can be carried out without any benefits. If we accept the classical definition of "culture" by Edward B. Tylor (1871): "culture is … complex whole which includes knowledge, belief, art, law, morals, custom, and any other capabilities and habits acquired by man as a member of society," we can find two fundamental functions of play for the existence of culture.

One of the functions is for the transmission of culture. As Sperber (1996) pointed out, cultural forms are stable and widely distributed just because children find them easy to think and easy to learn. If some activities can achieve playfulness for the next generation, such as children, these activities can be easily transmitted to them and sustained without special interferes such as education.

Another is the function for the innovation of culture. Play is always carried out in free and open rules by players. This aspect allows them to change the behaviors anytime and any ways as they like. Everything kept and continued by the adults can be easily thrown away and any traditional patterns can be revolutionized by the new generation simply because these do not attract the youths (Platon 360-350 BC; Benjamin 1969).

Caillois (1957) pointed out four essential elements of play, *agôn, alea mimicry* and *ilinx*, in his theory of universal grammar of play. These also can be analyzed and evaluated in the universal system of cultural transmission and innovation (Kamei 2010). The human activities related to cultural transmission and innovation, such as the education, teaching and leaning, have to be examined by this viewpoint of play theory.

Fieldwork in hunting-gathering societies

It has been pointed that hunting-gathering societies have neither educational institutions nor educational behaviors among their children. Hunter-gatherer children have their own culture, which is connected to the transmission of hunting-gathering culture. These were the results of my anthropological research in 1996-1998 among Baka children in the tropical rain forests in the East Region of the Republic of Cameroon (Kamei 2010).

Fifteen years later, with the further spread of schooling and the introduction of restrictions on hunting, how have children's culture and life changed? Are the characteristics of cultural transmission in foraging societies still maintained? This research aims to collect ethnographic data on children's daily activities including play, hunting, gathering, fishing, housework and so on. It also aims to describe the system of cultural transmission through this age group as one of the characteristics of foraging societies.

[Period] March 2012 (5 days); August-September 2012 (14 days)

[Field site] Settlements of Baka hunter-gatherers in the East Region, Republic of Cameroon [Methods] Participant observation and interviews with Baka children. Experimental methods on playing and learning activities were also adopted.

Results

Through participant observation and interviews among Baka children, the following points were found.

(1) School attendance rates have increased among both boys and girls, and consciousness of schooling is already shared among the majority of parents.

(2) Play and subsistence activities (hunting, gathering and fishing) conducted by boys and girls observed out of school have not changed [Case 1].

(3) Social and cultural changes among adults partly affect children's activities, but do not affect their way of playing and learning [Case 2, 3].

[Case 1] Fishing by girls. They form children's groups and go into the forests. They have experiences to hunt, gather and fish in the natural environments.

[Case 2] Slide play by boys. No teaching was observed among them. The elder boys only let the younger boys imitate their play behaviors.

[Case 3] Board game "*Songo*" by boys and girls. They learn how to behave first through the imitation, and how to play the game later without teaching.

Discussion

The results show that in the past fifteen years, children's culture and life have not changed. Observation and imitation are still the essential ways of learning among children. As before, it is rare to observe positive teaching activities among them. The characteristics of foraging societies "without education" are still maintained. Together with these observations, a "learning model of hunter-gatherer children supported by their play sense" can be presented in order to discuss the nature of "educational activities" by human beings.

"Play sense," perhaps universally shared among human beings as one of the functions of the brain, has to be examined to clarify the system of human culture. If we expect play sense as one of the factors of cultural transmission and innovation among the humans, especially as the factor of the different history of *Homo neanderthalensis* and *Homo sapiens*, "brain science on play," as well as "ethnographic studies on play," will become indispensable area of research for the investigation of human evolution.

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Why do wild bonobos not use tools like chimpanzees do? Examination of factors influencing the tool behaviors

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One of the most conspicuous behavioral differences among great apes is the paucity of tool use among wild bonobos (*Pan paniscus*) (Kano 1982; Ingmanson 1996; Hohmann and Fruth 2003) in comparison to chimpanzees (*Pan troglodytes*) who are one of the most prolific and skilled tool users in the animal kingdom (Sanz and Morgan 2007; Shumaker et al. 2011). This is in spite of the fact that bonobo tool use repertories are as large and diverse as chimpanzees in captive settings (Herrmann et al. 2010; Gruber et al. 2010), suggesting that the differences in cognitive abilities cannot fully explain the differences in tool using behaviors between these two species. This study on the differences in tool use behaviors and related factors between closely-related ape species might provide insights for understanding the differences in behaviors by Neanderthals and Modern Humans.

In this study, we compared tool using behaviors and potential drivers of these behaviors in the Wamba bonobo population located in central Democratic Republic of Congo with the Goualougo chimpanzee population of northern Republic of Congo. The tool use repertoire of wild bonobos was comprised of only 13 behaviors, compared to 42 for chimpanzees. However, the number of tool behaviors observed in each study site was similar between bonobos and chimpanzees, and many types of tool use for social, self-grooming/stimulation, and comfort/protection functions were commonly used by both species. A marked difference is that 25 of 42 tool behaviors exhibited by chimpanzees are performed for feeding, in contrast to a single report of bonobos using a leaf sponge to drink water.

We examined whether the differences in tool use repertoires can be explained by the necessity, opportunity, relative profitability, or invention hypotheses (Fox et al. 1999; Spagnoletti et al. 2012; Koops et al. 2013; Sanz and Morgan 2013). We found that habitat composition and fluctuation of fruit production at these two sites were similar, particularly when compared with variation observed between sites within each species. Thus it was unlikely that the necessity hypothesis explains the lack of tool use for feeding in bonobos. Though further study at Wamba is needed, we did not identify any obvious differences in prey availability that would indicate differences in tool using opportunities between the sites. This study could not test the relative profitability hypothesis, and further research is needed on whether tool use is the most efficient means of calorie or protein intake for wild apes. Bonobos at Wamba formed much larger and stable parties than chimpanzees at Goualougo, which was contrary to the prediction by the invention hypothesis.

Another explanation is that differences in tool use behavior between bonobos and chimpanzees might not be explained by the current ecological or social conditions, but rather by circumstances during the Pleistocene Epoch: the ability for tool use evolved only in chimpanzees under certain conditions in the past, and therefore chimpanzees currently living in all types of habitats inherently use tools for feeding while bonobos in any type of habitat do not. However, this hypothesis may not explain why there is no substantial between-species difference in ability for tool use under experimental conditions. The observed species differences might also reflect divergent behavioral predispositions, rather than actual differences in cognitive abilities. Chimpanzee tool use does not seem to be the most effective means of increasing energy intake, but may be performed when individuals have leisure time (Nishie 2011), while bonobos spend much of their leisure time in play and play is common among

adults (Enomoto 1990; Palagi 2006). Such differences in behavioral preference may explain why bonobos are likely to perform like chimpanzees in experimental conditions, but do not regularly perform tool use in natural settings.

This paper is in press in Behaviour with a title "why do wild bonobos not use tools like chimpanzees do?"

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Some differences between humans and other animals

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Knowledge about the behavioural and mental abilities of animals is important for understanding human evolution. However, it has been difficult to reach any scientific consensus about such abilities in birds or primates. This will be illustrated with some examples including short term memory, social learning and sequential behaviour. The second part of the talk is more theoretical and will discuss the behavioural and mental flexibility of animals, why animals sometimes appear smarter in the wild than in the laboratory, and whether or not animals can think. The presentation will end with some arguments why human like mental abilities have only evolved once.

Population change and cultural variation

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The human population has undergone explosive population growth since the beginning of the Holocene around 10,000 years ago. The effects of this population increase have been described in recent genetic studies (Keinan and Clark 2012), where it was shown that recent population expansions resulted in an increase over time in the number of rare alleles in the population. However, little work has directly addressed the effect of population expansion (or contraction) on the frequency distribution of cultural traits in the population. Here we introduce a cultural 'trait frequency spectrum' in direct analogy to the genetic 'site frequency spectrum' and examine the effects of population growth or decline on the distribution of cultural trait frequencies in a population. We use the simulation framework outlined by Fogarty et al. (in press) and compare the trait frequency spectra for populations using random oblique cultural transmission and best-of-k cultural transmission, elucidating the effects of population size as well as population growth. Finally, we comment on the implications of these findings for our understanding of human cultural evolution and cultural accumulation over time.

Why did the arts precede prehistoric settlement in Modern Humans ?

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Introduction

Why did only our species, Homo sapiens, leave behind artistic products, whereas other homo species, including Neanderthals, did not? The producers of art, or artists, might have suffered from much opportunity cost. One hypothesis is that different groups might have communicated well because of artists, who functioned as coordinators who connected individuals of different groups (Conkey 1980). Through the role that artists played, other groups might have been able to settle in an area and develop their own cultural traits. I introduce an agent-based model (ABM) simulation to test cultural accumulation in the time of the Replacement (Horiuchi and Kubota 2013), in order to simulate the dynamics of arts and settlement.

Methods

The ABM assumes 100 agents. They are uniformly distributed on the 10×10 cells. There are 10×10 cultural traits, c_i , each of which is unique to each cell, and is cumulative. Each agent gains cultural traits as the 10×10 matrix, $C(c_i \in C)$.

The agents have 10 units of effort. Each agent allocates his efforts among Hunter-gather (H), Settlement (S), and Arts (A). If an agent allocates e_b efforts to H, he gains the cultural trait of his residential cell, as well as those of his surrounding cells. Now, we define the distance between cell *i* and cell *j* as $x_{i,j}$. The agent of cell *i* gains the cultural trait of *j* as $e_b p^{x_{i,j}}$, where *p* is the discounting ratio of H ($0). If he allocates <math>e_i$ efforts to S, he gains the cultural traits of his residential cell as $e_i q$, where *q* is the effect of settlement ($q \ge 1$). If an agent allocates e_a efforts to A, he may be able to communicate with other agents from surrounding areas. Now the agent *i* allocates $e_{a,i}$ efforts to A. He communicates with the agent *j* if the value $e_{a,i} + e_{a,j} - rx_{i,j} > 0$ and is maximum, where *r* is the cost of communication (r > 0). While communicating, the two agents learn cultural traits from each other by the discounting ratio *s*; i.e., we assume that the cultural trait *k* of the agent *i* and *j* is $c_{k,i}$ and $c_{k,j}$ respectively. If $c_{k,i} < sc_{k,j}$ or $sc_{k,i} > c_{k,j}$, the cultural trait *k* of the agent *i* or *j* is improved up to $sc_{k,j}$ or $sc_{k,i}$, respectively (0 < s < 1). Naturally $e_b + e_s + e_a = 10$. The payoff of the agent is equivalent to $\sum c_j u^{x_{i,j}}$, where *u* is the discounting ratio of other cultural traits (0 < u < 1).

At the initial condition, all agents allocate all their efforts to H. In the simulation, the agents change their allocation of efforts successively through trial and error, to maximize their payoff. The ABM verifies the condition and process by which the agents allocate their efforts to S or A.

Results

Since the ABM has many independent variables, p, q, r, s, and u, herein I set the parameters (q, r, s, u) = (2, 1, 0.5, 0.5) and change only p to simplify the analysis. When p = 1, all agents keep their efforts at (H, S, A) as (10, 0, 0). When p = 0.5, however, an increasing number of agents allocates their efforts from H to S as time passes, while a few agents allocate their efforts from H to A (Fig. 1). A communication network appears where artists, who

allocate much effort to A, are situated at the hub positions (Fig. 2). At t = 30,000, the agents are classified into three groups on the basis of their position in the network (Fig. 2b); the agents of each of the three groups have unique sets of cultural traits that are distinguishable from other groups.

I ran 20 simulations for each p, from 1 to 0.2, and verified the results at t = 30,000. Figs. 3, 4, and 5 respectively show the box plot of the payoffs of agents, the ratios of agents who belong to the largest group, and the sum of the cultural trait of each cell gained by the residential agent.

Discussion

If agents are less likely to gain cultural traits by H, they start to shift their efforts from H to S or A. Many agents allocate all their efforts to S, whereas a few agents specialize in A. Although they gain few benefits from H, they may gain much payoff by shifting their efforts to S and are coordinated by the agents of A. The agents of A work well as coordinators, who let other agents allocate their efforts to S.

The present ABM suggests the process of civilization. First, some individuals work as artists and coordinate communication among different groups; then, most individuals start a settlement and more cultural traits develops in the entire population. The reason why individuals started creating art is that there were few benefits from hunting-gathering because of severe environmental conditions, such as during the glacial period. In the presentation, I show how the agents of A are distributed through computer simulations. Future research may predict the areas where artistic products were made by Modern Humans in prehistoric times.



Fig. 1 Average efforts to H, S and A of all agents along time (0 < t < 100,000).

sverage payoft



Fig. 3 Average payoffs of agents at different p.



Fig. 2 Communication network coordinated by artists. The hub agents really allocate much efforts to A. (a) t = 10,000. (b) t = 30,000.



Fig. 4 Maximum cluster of agents at different p.



Fig. 5 Summed cultural traits by agents at different p.

Population and culture: A theoretical basis for dramatic regime shifts?

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Model and analysis

Malthus proposed that "population equilibrates with resources at some level mediated by technology," whereas Boserup believed that "technological change is itself spurred by increases in population" (quoted from Lee 1986). Many Palaeolithic archaeologists currently emphasize the Boserupian premise in interpreting major changes in stone tools or other cultural artefacts. In the seminal paper cited above, Lee presents a coevolutionary model for population and technology that synthesizes the contrasting viewpoints of Malthus and Boserup. Richerson and Boyd (2013) have recently discussed the importance of adopting such an approach in understanding progressive and regressive cultural changes during the Palaeolithic. Here, we describe and analyze a minimal mathematical model, in the spirit of Ghirlanda and Enquist (2007), that instantiates the verbal model of Richerson and Boyd (2013).

For a population let us denote its mean cultural (technological) level by and its size > 0 and its size by N > 0. We assume the dynamic

$$\frac{d\bar{z}}{dt} = -\alpha \bar{z} + \beta (\varepsilon + \log N), \tag{1}$$

for the mean cultural level resulting from error-prone social learning, where α and β are positive parameters, and $\varepsilon \approx 0.577$ is Euler's constant (Henrich 2004; Mesoudi 2011). Next, assume the logistic model of population growth,

$$\frac{dN}{dt} = rN \left\{ 1 - \frac{N}{K + D \frac{e^{c(z-z^*)}}{1 + e^{c(z-z^*)}}} \right\},\tag{2}$$

where r, c, z^* , K, and D are positive parameters. The assumption here is that the cultural level of an individual does not contribute to the biological fitness of that individual, perhaps because resources are shared, but that the mean cultural level of a population, \overline{z} , determines—has a positive effect on—the carrying capacity of the population.

Make the transformation of variable $x = c(\overline{z} - z^*)$, which yields

$$\frac{dx}{dt} = -\alpha x - \alpha c z^* + \beta c (\varepsilon + \log N), \qquad (3)$$

and

$$\frac{dN}{dt} = rN \left\{ 1 - \frac{N}{K + D \frac{e^x}{1 + e^x}} \right\}.$$
(4)

The equilibria of the system, which must simultaneously satisfy $\frac{dx}{dt} = 0$ and $\frac{dN}{dt} = 0$, are given by the intersection(s) of the exponential curve

$$N(x) = me^{\lambda x/c},$$
(5)

where $\lambda = \alpha / \beta$ and $m = e^{\lambda z^* - \varepsilon}$, with the sigmoid curve

$$N(x) = K + D \frac{e^x}{1 + e^x} \,. \tag{6}$$

Fig. 1 below depicts the phase plane for the model with the transformed cultural level, $x = c(\overline{z} - z^*)$, on the horizontal axis and population, *N*, on the vertical axis. The parameter values are $\lambda = 0.2$, c = 6, $z^* = 18$, K = 10, D = 30. In this case, the blue curve which is the plot of Eq. (5) (the Boserup line) and the red curve which is the plot of Eq. (6) (the Malthus line) intersect three times to yield three valid equilibria (that satisfy $\overline{z} > 0$).

The directions of change in the various regions of the phase plane are given by Eq. (3) and Eq. (4) and indicated by black arrows. They show that the two outside equilibria—the ones on the right and left correspond to high and low culture regimes, respectively—are locally stable whereas the middle equilibrium is unstable. Hence, we have bistability in this case.

Fig. 2 below with $\lambda = \alpha / \beta$ on the horizontal axis and $x = c(\overline{z} - \overline{z}^*)$ on the vertical axis shows that this numerical example exhibits hysteresis. Parameter λ is a measure of innovativeness, with smaller values corresponding to greater innovativeness (Kobayashi and Aoki 2012). The other parameters are set at c = 6, $z^* = 18$, K = 10, D = 15. The two solid lines denote alternative locally stable equilibria—high and low culture regimes—whereas the broken line gives the unstable equilibria.

Fig. 2 suggests the following scenario for changes in cultural level when an evolutionary increase in innovativeness occurs (\blacksquare decreases). Initially, there will be a gradual increase in cultural level along the lower solid line representing equilibria at the lower cultural level. Then, when λ passes a critical threshold ≈ 0.1677 known as a "catastrophic bifurcation", there will be a regime shift to an equilibrium at the higher cultural level represented by the upper solid line. Empirically, this sudden shift may be observable in the archaeological record as a "creative explosion." If for some reason innovativeness subsequently declines, the cultural level will gradually decrease along the upper solid line of equilibria. Then, when λ passes the other critical threshold ≈ 0.2037 , a regime shift occurs to the lower stable line. The forward and backward switches follow different paths, i.e. we have hysteresis.

Hysteresis is also observed when the "cultureless" carrying capacity, K, is varied with the other parameters held constant.

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Learning schedule and cultural evolution: COS and ESS

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Introduction

In the evolution of Modern Humans, innovative stone tools might have played an important role. Advanced and complex lithic industries can never be invented by a single individual without building on knowledge acquired from others. They are the results of cumulative cultural evolution in which knowledge is inherited from parental generations and passed on to descendant generations. However, if all individuals simply copied what was already known, there would be no advancement in technology. Contribution to culture by improving on the preceding knowledge, such as a discovery of new adaptive use or form of stone tools, is also crucial for cultural evolution. Thus, it is an important problem to determine what learning strategy can support the cumulative culture that develops the fastest: when and how should an individual perform learning during one's life?

The balance between the time allocated to learning and the time allocated to the exploitation of the learned knowledge is then the next question. To maximize the accumulation rate of culture, one should spend sufficient time to absorb the existing knowledge in the parental generation and then spend all the rest of the lifetime to improve the knowledge by individual learning. However, such a learning schedule does not necessarily maximize the fitness of an individual, i.e., the expected number of biological offspring. The ultimate goal for an individual is the maximization of the benefit provided from the knowledge or culture, not the maximization of the knowledge itself.

Previous theoretical studies

Theoretical researches surveying the evolution of leaning as life-history strategies have started only recently. One of the well-known studies on a leaning schedule is Social Learning Tournament (Rendell et al. 2010). However, the Tournament included so many factors and the analytic treatment is impossible. Enquise et al. (2007) compared the performances of pure SL strategy, pure IL strategy, and "critical social learner" who performs individual learning (IL) only if social learning (SL) had failed to achieve OK solution. They showed that critical social learner outperforms the pure strategies and thus evolves. Aoki et al. (2012) performed a more exhaustive study of a two-stage model in which any mixture of SL and IL is allowed in each stage and the environment may fluctuate. They showed that in a constant environment pure SL followed by pure IL is evolutionarily stable strategy when the efficiency of SL is not too low.

In a series of studies on the evolutionarily stable learning schedule, Lehmann et al. (2013) studied a case when trade-off between learning and exploiting exists. This model is complex as it includes many factors (i.e., continuous time axis, horizontal transmission, and environmental changes). One of their results is that, when environmental change is negligibly rare, the equilibrium of the cultural level realized by the evolutionarily stable learning schedule is not very high compared to the level realized by the pure IL strategy. This result is counterintuitive because improvement achieved by IL should accumulate over generations when environmental change is rare (a sufficiently small decay rate of information), and thus we naturally expect the cultural level to increase to reach the maximum level that is transmittable to the next generation (limited only by the efficiency of SL).

However, the predicted cultural level was far below this level.

Aim of study

The goal of the present study is to clarify the factors that facilitate or suppress the cumulative cultural evolution over generations. When and how does the maximization of individual fitness (natural selection) also maximize the cultural level of the society after a sufficient number of generations? For this purpose, we study a relatively simple model with a two-stage life history when there is trade-off between learning and exploiting.

Model

A learning schedule considered here is a broad developmental pattern over a single individual's lifetime in the differential use of IL and SL with regard to behaviors that may take a long time to be acquired. It differs from the ordered application of IL and SL in skill acquisition at any one time, which may occur repeatedly during one's lifetime.

Allocation of effort is the evolving strategy in this study. In the first stage, an individual performs IL with effort and SL with effort $1-u_0$. In the second stage, the individual allocates the learning effort to IL and SL with a ratio $u_1:1-u_1$. During this second stage, the individual can reproduce offspring. Reproductive success is determined by two factors; cultural level and the effort put in reproduction. Most animals including human can learn something before the body sexually matures. It also seems adaptive to allocate more learning effort in the earlier stage of life than allocating learning effort equally in all life stages. Thus, we assume that an individual does not reproduce in the first stage. In the second stage, the fraction v of time is dedicated to learning, and the fraction 1-v to exploiting the knowledge for reproduction. Thus in the second stage, efforts u_1v , $(1-u_1)v$, and 1-v are allocated to IL, SL, and exploitation, respectively. The life history strategy is represented by the triplet (u_0, u_1, v) .

Result

We are interested in a case when the efficiency of SL is sufficiently large. Otherwise cultural accumulation never occurs. If there is no trade-off between learning and exploitation, a learning schedule performing SL then IL is predicted. Thus, if the SL efficiency is sufficiently high, the equilibrium of the cultural level can increase to almost infinity. However, when a trade-off between learning and exploitation exists, COS and ESS are completely different.

Coordinated-Optimal Strategy (COS)

COS is such a learning strategy that maximizes the equilibrium value of fitness when all individuals in population adopts this strategy. The idea is similar to the concept of the Pareto-optimality where payoff of a certain player cannot increase without decreasing payoff of another player. COS would be realized when all individuals behave as if they would cooperate to maximize the fitness (benefit) of a group in <u>far future</u>. In a simple model (Wakano and Miura 2014), COS predicts cultural accumulation.

Evolutionarily Stable Strategy (ESS)

ESS is such a learning strategy that any other strategy yields lower fitness when all individuals adopts this strategy. It is sometimes referred to as undefeatable strategy. ESS would be realized when all individuals behave as if they would try to maximize the fitness (benefit) of himself/herself (and hence, interested only in <u>immediate benefit</u>, not future). In a simple model (Wakano and Miura 2014), ESS predicts no cultural accumulation.

Discussion

If learning schedule is genetically determined, the ESS should evolve. In a simple model, it is IL-only strategy. Thus, cumulative culture never evolves. The model neglects so many factors such as cooperative information transfer among relatives (e.g., from parent to offspring), thus such factors might explain the observed cumulative culture in Modern Humans. Another possibility is that learning schedule itself is cultural trait, i.e. learned. Under this hypothesis, the COS might be predicted, but it will result in a highly hierarchical model which is difficult to analyze. Human developmental pattern (e.g., body and brain growth curve) represents the restriction on learning behavior of an infant/child/juvenile and it must have close relationship with human learning schedule. The connection between the study on learning schedule and the study of human development might provide a way to explain the evolution of cumulative culture.

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DAY 6: December 5, 2014 Cognition and Learning

Cognition and Learning Looking into the Neanderthal Brain Closing Remarks

The beginning of symbolic art and the learning cycle in nature

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A bunch of modern behavior that characterize Modern Humans has developed gradually in the Middle Stone Age of Africa after the emergence of "anatomically Modern Humans" around 200 ka (McBrearty and Brooks 2000). There were various objects supposed to have symbolic meaning such as burial accompanied with artifacts, ornaments like beads and pendants, cave art and fine sculptures, and so on. For beads and pendants, the date of fabrication seems to go back to 40-50 ka, and some ostrich eggshell beads were found as fabrication of 83 ka. Pigments seems to have been in use from more than 50 ka. On the other hand, artistic paintings and sculptures had not appeared until the upper paleolithic in Europe.

The production of symbolic art has diffused in Europe rapidly after the replacement of Neanderthals by Modern Humans. The oldest cave paintings were found at Chauvet in southwestern France, which is dated back to ca. 32,000 BP. The most conspicuous feature of early cave art is that the paintings mostly consisted of large animals such as bisons, aurochs, horses, red-deers, reindeers, and ibexes being depicted in an astonishingly vivid and beautiful forms. Human pictures are extremely rare and they are mostly represented in a childish manner, seriously abstracted and deformed, and sometimes as a therianthropic appearance. The reason why people began to create such artistic representation after the replacement is not clear at all. But judging from the accurate and vivid animal images, it seems doubtless that people who created such paintings had great interest to nature, in particular to large animals living in their vicinity. It seems that humans have awaken to the splendidness of nature and animals. Before the replacement period animals were just targets of hunting for humans, either modern or Neanderthal, and sometime around the replacement, utterly different ideas about animals were born and developed in human mind.

Today's hunter-gatherers have two approaches to wild animal world: one is natural historical approach and the other is sympathetic approach. These two approaches make up the most important part of the life of hunter-gatherers. Hunter-gatherers go stroll about nature and explore the environment for new information everyday: people pickup any changes in the environment such as the new traces of animal footprints, fruit ripening smell, color of tree blossoms, the sound and movement of honeybees, and so on. As getting various information from the environment people make prediction following indigenous eco-models or theories about natural phenomena and adjust their foraging plan. If the prediction comes true, the information is recognized to be useful and accumulated in their knowledge archives. The accuracy and wideness of knowledge about nature in hunter-gatherers are well documented by many ethnologists and biologists: one report says that "the !Kung appear to know a good deal more about many subjects than do the scientists." (Blurton-Jones and Konner 1976).

On the other hand, hunter-gatherers have a quite different approach, a sympathetic one to animals. Although animals are the objects of hunting activity, they are also admirable companions sharing the same natural environment with humans and showing abilities which surpass humans. People try to understand the animals sympathetically through intuition, mind-reading or theory of mind, and anthropomorphic interaction. Among hunter-gatherers it is quite commonly believed that humans can communicate with animals and that makes a key point in hunting process.

The sympathetic approach to animals opens a new way to human learning behavior. Pedagogy is one of the useful

methods of learning among humans, which consists of interaction between the teacher and the learner in an educational context. The relationship between the teacher and the learner is crucial point for obtaining expected results in pedagogy. Outside the school institution, the teacher is not confined to experts, and even those who simply watch over the learner can be a teacher as long as there is mutual recognition between the teacher and the learner. And this pattern can be extended even to animals. For example, a hunter who wants to understand the behavior of bears can learn from the bear by regarding the bear as the teacher, following it and imitating everything it does. In repeating such learning, the hunter will finally find himself totally behaving like the bear. The hunter becomes to know what the bear will do next moment. This is a kind of imitative social learning and also a kind of meta-learning in which the learner has to monitor ones own learning process all the time following and imitating the animal.

Either by the natural historical approach or the sympathetic one, hunters place themselves deep in the environment and hear sounds and feel moves of nature. The two approaches look like two different ways to arrive totally different goals, but actually they interrelate with and complement each other to make an organized body of knowledge called TEK (traditional ecological knowledge.) It is a synthetic knowledge consisting not only of natural, but also of social and cultural elements.

Nature being marked with its miraculous complexity, richness of detail and variability, brings humans infinite opportunity for discovery and new learning. It may not be an exaggeration to say that all ideas of human beings, thoughts and imaginations have been derived from nature. There is a learning cycle for hunter-gatherers in relation to their natural environment. It starts with enormous interest in nature that motivates hunters to explore the natural environment with careful attentions and observation. Acute and meticulous observation brings about discovery which turns into knowledge and understanding. The ability of discovery gives birth to creative behavior and arouse more interest in nature.

The intimate knowledge about nature and animals accompanied with excitement of discovery might have awaken the upper paleolithic hunter-gatherers to create the splendid cave art. The learning cycle in nature is supported by cognitive development, theory of mind or mind reading, flexible or fluid intelligence, and meta-learning. Sociality is another indispensable factor in that cycle because the communication with nature is based on the idea of relatedness between humans and animals and other nonhuman creatures in nature.

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The ability of objectification as the basis for cultural learning and creativity: Teasing as the device for training children in Canadian Inuit society

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The purpose of this presentation is to examine socio-cultural backgrounds of the Inuit adults' teasing children and disclose its real purpose behind it in order to consider the evolutionary basis of the learning ability of Modern Humans and thus build the hypothesis about the difference in learning ability between Neanderthals and Modern Humans. Firstly, based on the Bateson's model regarding the evolution of learning, I will examine the hypothesis of 'cumulative cultural evolution' proposed by Tomasello in order to modify Tomasello's model to include the evolutionary process of learning ability from Neanderthals to Modern Humans. Then, I will return to some examples of the Inuit adults' teasing children in order to understand its characteristics. Moreover, I will situate it in the socio-cultural backgrounds of the learning process of Inuit children and show that the teasing functions as the device for education of the art of patience, which is the emotional basis for observation learning and creative invention. Finally, based on the results of these analyses, I will propose the hypothesis that the most important ability required for full achievement of 'cumulative cultural learning' is the ability to objectify and manipulate the relationships between oneself and the environment, which might distinguish Modern Humans from Neanderthals.

Neural correlates of coping strategy for boredom: Its relationship with creativity

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Introduction

Boredom is a negative emotion that is characterized by the lack of meaning one feels from repeated exposure to the same stimulus or repeated performance of the same actions. Coping strategies for feeling bored are candidate cognitive processes that may explain the creativity of Homo sapiens. Technological innovation and cultural development may be in part the result of coping against feeling bored in humans. Functional neuroimaging studies have recently started exploration of the neural mechanism of boredom (Malkovsky et al. 2012; Mathiak et al. 2013), while the neural bases of the coping system for boredom is yet to be addressed. In this study, we addressed specifically the approach coping, which is to somehow cope with the stress rather than to run away from it. There are two types of strategies in approach coping: behavioral coping (BC) and cognitive coping (CC) strategies (Holahan et al. 1987; Nett et al. 2010). The BC strategy involves tying to actually change the stressful situation of boredom, while the CC strategy involves changing one's own perception of the situation. The purpose of this study was firstly to clarify the neural mechanisms of the two strategies of approach coping with boredom using functional Magnetic Resonance Imaging (fMRI). We also attempted to clarify the association between the neural correlates of the coping strategies and creativity.

Methods

Forty-six healthy right-handed university students participated in this study. Written informed consent was obtained from each subject and the protocol was approved by the Ethics Committee of Tohoku University. In the MRI scanner, the subjects alternately performed an Appreciation task, in which they viewed a visual stimulus, such as a photo or drawing (4s), and an Evaluation task, in which the subjects rated their degree of boredom during the preceding Appreciation task using a four-grade scaling (1: Want to see the same stimulus - 4: Want to see a new stimulus; 1s). When the subject selected 1, 2, or 3 in the Evaluation task, the same stimulus was presented in the subsequent Appreciation task. When the subject selected 4, in the subsequent Appreciation task, he/she could see a new stimulus at 50% probability. When a new stimulus was not presented, the subject selected 4 again and a new stimulus was presented in 50% of the cases in the following Appreciation task. We hypothesized that BC activity would occur just before the first selection of 4 for each stimulus, and CC activity would occur at the second or more presentations of the same stimuli after the first selection of 4. We analyzed neural activity during the appreciation task on SPM8 using a GLM with the following four regressors: (1) average response to the stimuli, (2) parametric modulation on the response by the boredom rating, (3) activity just before the first selection of 4 for each stimulus, and (4) activity for the second or later presentations of the same stimuli after the first selection of 4. The regressors (2), (3), and (4) capture the neural response relevant to the feeling of boredom, the BC strategy, and the CC strategy of the boredom coping, respectively. To examine the association between the neural correlates of the coping strategies and creativity, across-subject voxelwise single-regression analysis with the creativity score was adopted to the estimates for the regressors (3) and (4). The creativity score was measured using the S-A creativity test (Society for Creative Minds 1969), which assesses the degree of divergent thinking (Guilford 1967).

Results

The data of 45 subjects (19 females, aged 20.6±1.96) were analyzed. The neural response to the boredom feeling was identified in the bilateral supramarginal gyrus (SMG)/angular gyrus (AG), the right superior/middle frontal gyrus, the right precuneus, the bilateral inferior frontal gyrus, the left orbital surface (Fig. 1). Activation during the boredom coping using the BC and CC strategies are shown in Figs. 2 and 3. Irrespective of the strategy, neural activity related to boredom coping was identified in the ventromedial prefrontal cortex (vmPFC). Comparing the two different strategies, neural responses specific to the BC strategy were observed in the left post central gyrus, bilateral anterior cingulate cortex (ACC), cuneus. Those to the CC strategies were identified in the bilateral middle temporal gyri (MTG), the right insula, the dorsomedial prefrontal cortex, the right posterior cingulate cortex, and the right AG. As a result of regression analysis, we found a significant positive effect of the creativity score on the estimates for the regressor (4) alone in the right superior temporal gyrus/lolandic operculum/insula (Fig. 4).

Discussion and conclusion

We found the neural mechanism for coping with boredom, as well as the neural response related to the boredom feeling. The results suggest that the vmPFC is related to the boredom coping irrespective of the strategies. We consider this area to select the coping strategy: behavioral or cognitive. Previous studies suggested that this area is involved in the control of attention toward the external environment or the execution of ambivalent evaluations (Gilbert et al. 2006; Nohlen et al. 2013). Furthermore, the vmPFC is considered to be essential for thinking about the future, given its relevance to delay discounting (Cooper et al. 2013). The left post central gyrus and ACC identified for the BC strategy seemed to be relevant to behavioural output considering their known role in the motor preparation (Zang et al. 2003). Bilateral MTG identified for the CC strategy appears to play a key role in boredom-driven creativity based on the role of the regions in the semantic processing (Ruff et al. 2008) and execution of a creative task (Zhao et al. 2013). The observed relationship between the creativity score and activation for the CC strategy in the right superior temporal gyrus/Rolandic operculum/insula in CC suggest that the emotional processing implicated in this region (Craig 2002, 2011) may be a key mediator of the boredom-driven creativity. These findings support the importance of boredom and the cognitive coping strategy for it in the creativity of Homo sapiens and suggest possible neural mechanism underlying these dynamics.

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The evolution of the parietal areas in Neanderthals and Modern Humans: From bones to mind

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The major form change associated with the evolution of the Modern Human brain is a marked dilation of the upper parietal surface. An early post-natal morphogenetic stage in Homo sapiens is responsible for this parietal bulging, and this stage is absent in chimpanzees and Neandertals. Such evolutionary change has been hypothesized to be associated with deep parietal elements, like the precuneus or the intraparietal sulcus. Both areas are involved in visuospatial integration. According to theories of Extended Mind, cognition is deeply rooted into the body experience, being the body the interface between brain and environment. In this process, visuospatial integration functions are particularly important, managing the integration between inner (body) and outer (environment) coordinates. The main ports of such interface are the eyes and the hands, and the intraparietal sulcus represents a main node of their coordination. Dental evidence suggests that Neandertals used normally to rely on the mouth for praxis, although such choice put seriously at risk its essential functions. Taking into account that Neandertals had a complex culture but lack the parietal dilation displayed by Modern Humans, we can wonder whether their visuospatial capacity required the involvement of an additional component in their body interface, because of a mismatch between biological and cultural evolution. This hypothesis in cognitive archaeology may be tested and evaluated considering other visuospatial behaviours in extinct hominids, as well as investigating in Modern Humans the visuospatial functions and the eye-hand system according to the principles of extended mind.

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Looking into the Neanderthal Brain

Estimating the extent of brain subdivisions using skulls

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Understanding the structure and cognitive functions of fossil hominid brains is one of the most important issues in anthropology. However, due to the lack of the soft tissue in fossil skulls, we need to infer the structure and functions of the brains indirectly based on the skull morphology. To infer the outer shape of the brains, researchers have been using endocranial casts. Although meninges and cerebrospinal fluids intervene between the skull and the brain, they are relatively thin compared to the skull size, and allow approximate estimation of the volume and the outer shape of the brain. To obtain further information from the skull, we need to infer the sulcal and gyral patterns of the brain and determine the extent of major subdivisions of the cerebral cortex. We thus focus on the correspondence of endocranial impressions to cerebral sulci and gyri, as well as on the relationship between the locations of cerebral sulci and cranial sutures.

The sulcal and gyral patterns of the brain were clearly observed on the endocasts in prosimians and in smallsized species in anthropoids. However, there is a long history of discussion on the relationship of endocranial impressions to cerebral sulci and gyri in hominids. Several of the earliest studies in hominid skulls showed convolutional patterns on the endocasts, and identified the corresponding cerebral sulci; for example, in La Quina, La Chapelle aux Saints, "Sinanthropus", and "Pithecanthropus erectus".

In terms of the validity of those inferences, Symington (1916) criticized the simple assumption of the correspondence of endocranial morphology to cerebral convolutions and stated that "the simplicity or complexity of the cerebral fissures and convolutions cannot be determined with any degree of accuracy from endocranial casts." Le Gros Clarke (1936) generally supported Symington's view in his paper on the comparison of endocasts and brains of chimpanzees, and Ogawa et al. (1970) also stated that Symington's explanations were more plausible in their study on the Amud endocast. Smith-Agreda (1955) examined more than 300 Modern Human skulls and found that impressions corresponding to cerebral gyri were observed typically in the anterior and middle cranial fossa, and to a lesser extent on the inner surface of the lateral wall of the skull. These findings indicate that the inference of the cerebral gyri and sulci using the skull might be reliable in the basal portion of the skull but increasingly difficult towards the vertex.

We have been approaching this issue based on the skulls and brains of extant primate species including human. First, we confirmed that most of the major sulci were identified on endocasts in *Macaca fascicularis* (Kobayashi et al, 2014a). We determined not only the locations of major sulci on the endocasts, but also observed individual differences of some sulcal patterns. We next analyzed the dry skull specimens of 10 primate species, and compared the impressions on their endocasts with the sulcal patterns of brains that were so far reported in the literature. As in the *Macaca fascicularis*, major sulci were identified on the endocasts in a lemur, most monkeys, and a gibbon although no marked correspondence was observed in a chimpanzee. Moreover, convolutional patterns were obscured in the parietal region particularly in *Macaca fuscata*, which have the largest skulls among the monkeys we analyzed. We also observed that endocasts of human infants exhibit more obvious impressions than in adults although their correspondence to cerebral sulci and gyri is not always clear. These findings indicated that impressions on the endocasts are more marked in smaller skulls, and are obscured particularly on the dorsolateral surface in larger skulls, such as adults of greater apes and humans. It prompted us to analyze immature individuals

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of greater apes and humans. We will present the outline of the data that were obtained in collaboration with Christoph P. E. Zollikofer and Marcia Ponce de León at the Anthropological Institute, University of Zürich.

Concerning the location of the precentral sulcus, Flatau and Jacobsohn (1899) already illustrated the close relationship between the precentral sulcus and the coronal suture in the macaque, chimpanzee, and human. Even in lemurs, which lack a homologue of the precentral sulcus, the cytoarchitectonic border obtained in later studies (Brodmann 1909) lies close to the coronal suture. We re-evaluated the relationship between the sulcus and the suture using modern techniques.

By comparing the CT images of the skull and the brain in *Macaca fascicularis*, we determined that the lower limb of the arcuate sulcus and the lower half of the coronal suture were closely located (Kobayashi et al. 2014b). In other primate species, we confirmed similar relationships but also found that there were some individual and species differences. In the modern Japanese, we analyzed the relationship using two different methods. First, we created thin-layer silicone endocasts of the calvarias and compared the location of the coronal suture with that of the precentral sulcus determined on the brain. The lower portion of the precentral sulcus is located posterior to the lower half of the coronal suture. It indicates that the caudal border of the prefrontal cortex shifted caudally in the human compared to the monkeys. To evaluate the accuracy of the silicone endocast method, we also analyzed 2D- and 3D-CT and MR images of Modern Human skulls and brains that were found to be normal on CT and MR imaging. The results showed relationships between the precentral sulcus and the coronal suture that were consistent with the silicone endocast findings. Further evaluation of this approach will be necessary, for example in greater apes, before we apply it to fossil hominids.

Our findings thus showed both the possibilities and limitations of the inference of the cortical subdivisions based on the skull morphology. Data on smaller and immature individuals might play a key role in the inference of the brain structure and functions of fossil hominids.

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Looking into the Neanderthal Brain

Inferring fossil brains from endocasts: New methods and results

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Human evolution is characterized by two key processes: transition from quadrupedal to bipedal locomotion, and transition from large-faced/small-brained species to small-faced/large-brained species. While evolutionary changes in brain size can be inferred from endocranial volume measurements, evolutionary changes in brain shape and brain organization are more difficult to track. The principal challenge is to infer the external morphology of the brain from the morphology of the endocranial cavity, and to infer structural and possibly functional changes in the brain from its external morphology. Here we present new concepts and methods of endocast-brain inference. One approach is to use methods of forensic soft tissue reconstruction. While these methods have been designed to reconstruct "external" soft tissues such as the face, the underlying concepts can also be applied to reconstruct "internal" soft tissues such as the brain. Another approach is to use clinical CT and MRI data to characterize the relationship between the endocranial cavity and the brain in living subjects. Together, these methods provide new insights into possible structural reorganization of the brain during the course of human evolution.

Estimating the cerebral and cerebellar volumes of Neanderthals and Middle and Upper Paleolithic *Homo sapiens*

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Introduction

The trajectories of brain size increase in the hominin lineage have been revealed by many fossil studies because endocranial volume is the good estimator for brain size. Yet, we have only limited knowledge about the fossil brain substructures due to difficulties to estimate them, including the cerebellar size in the hominin lineage. Weaver (2001, 2005) reported that the cerebella of Neanderthals and Cro-Magnon 1 were smaller than those of the recent Modern Humans. Weaver (2010) discussed the association among the brain, gene and cultural evolutions in the Late Pleistocene, postulating that the relative cerebellar size did not reach the recent modern condition until some time after 28,000 years BP.

On the other hand, Kubo et al. (2014) pointed out that the Weaver's estimation method for cerebellar volume is not useful to apply to Modern Humans (and probably the close hominin relatives like Neanderthals) due to the nature of the reference sample and likely affected by the inappropriate calibration. Thus, the cerebellar volumes of Neanderthals and Cro-Magnon 1 have to be re-examined. In addition, because there is no report about cerebellar volume estimates for earlier Modern Humans older than Cro-Magnon 1, it remains unclear whether the Late Pleistocene *Homo* including Neanderthals and early Modern Humans shared relatively small cerebella.

We previously reported a new method to estimate cerebellar volumes from endocasts, which was devised by using MRI data of a living Modern Human sample (Kubo et al. 2014). This paper reports a method to estimate cerebral volumes from endocasts, and then calculates the cerebral/cerebellar volumes of fossil specimens including Neanderthals, Cro-Magnon 1, and Middle Paleolithic Modern Humans. We compare the cerebellar volume fraction within the whole brain volume among these Late Pleistocene *Homo* specimens and living human sample in order to assess whether the relatively small cerebellum is an ancestral condition (to the recent Modern Humans) shared among early Modern Humans and Neanderthals.

Materials and methods

First, we investigated the volumetric relationships between endocranial subdivisions and brain parts in a reference sample consisting of thirty-two healthy Japanese subjects (18–22 years-old; 16 males and 16 females) in order to devise a method to estimate the cerebral and cerebellar volumes from skulls.

We measured the volumes of cerebrum (V_{CBR}), cerebellum (V_{CBL}), endocranial cavity (V_{EC}), and two endocranial parts (V_{PCF} and V_{UEC}) of the reference sample based on the magnetic resonance imaging (MRI) data with reconstructed voxel resolution of ~1×~1×1 mm. V_{PCF} is synonymous with PCFV in Kubo et al. (2014), which is a substantial volume of the posterior cranial fossa (PCF) region except for a small portion anterior to the opening of the internal acoustic meatus and basion. V_{UEC} is the volume of the upper endocranial cavity, which excludes the whole PCF region (i.e. V_{PCF} and the aforementioned small portion). We then calculated the correlation

coefficients and reduced major axis (RMA) equations between V_{CBL} and V_{PCF} and between V_{CBR} and V_{UEC} , respectively.

The RMA equations are primarily to be applied to the volumes derived from computed tomographic (CT) data, while the V_{PCF} and V_{UEC} values of the reference sample are derived from MRI data, which might have some systematic error relative to the CT-based measurements. Hence, before calculating the RMA equations, we calibrated the V_{PCF} and V_{UEC} values of the reference sample by multiplying by factors of 1.002 (for V_{PCF}) and 1.014 (for V_{UEC}) respectively, which were the ratios derived from paired comparison between the CT and MRI measurements of the same individuals (n=3).

We then estimated the V_{CBR} and V_{CBL} of fossil crania by using the RMA equations thus determined. The fossil sample includes two Middle Paleolithic *H. sapiens* from Levant (Skhul 5 and Qafzeh 9), an Upper Paleolithic *H. sapiens* (Cro-Magnon 1), and four Neanderthals (La Chapelle-aux-Saints, Gibraltar 1, Amud 1, Teshik-Tash). The V_{EC} , V_{UEC} , and V_{PCF} of Teshik-Tash were taken from the CT imagery of the plaster endocast. Those of the other fossil specimens were taken from the endocranial models which were reconstructed from the CT data of the original crania. The substantial missing parts of Amud 1 and Gibraltal 1 endocasts were interpolated by the preserved parts of Gibraltal 1 and La Chapelle-aux-Saints (see Ogihara et al.'s paper in this conference for more details).

As a measure of the relative cerebellar size, we also calculated 'volume fraction of cerebellum' (FCBL), which is the proportion of the V_{CBL} within the total brain volume (V_{TOT}). The V_{TOT} estimates are obtained by multiplying the sum of V_{CBR} and V_{CBL} by a factor of 1.0143, which is derived from the volumetric data of the brain parts (e.g. the medulla oblongata and mesencephalon) of a human cadaver (Stephan et al., 1981). We compared the V_{CBL} , V_{CBR} , V_{TOT} , and F_{CBL} estimates among four groups (i.e. Neanderthals, Middle Paleolithic *H. sapiens*, Upper Paleolithic *H. sapiens*, and recent Modern Humans) by performing Mann-Whitney U test with Holm correction. In addition, we calculated the FCBL estimates based on the data of Weaver (2001) for comparison. Weaver (2001) reported the brain weight estimates of the fossil sample. Hence, we converted the weight values into V_{TOT} by a factor of 1.036 from Stephan et al. (1981).

Results and discussion

The V_{PCF} and V_{CBL}, and the V_{UEC} and V_{CBR} in the living human sample were highly correlated respectively (Pearson's correlation coefficient: 0.884 and 0.944). Hence, we can reasonably assume that the two endocranial metrics are useful estimators for the cerebral/cerebellar volumes as far as the estimation is applied for the fossil specimen whose endocranial size or shape is not so far from that of the living Modern Humans. Based on the volumetric relationships, we determined two RMA equations for V_{CBL} and V_{CBR} estimation (Fig. 1, V_{CBL} = 0.775 V_{PCF}+39.5; V_{CBR} = 0.834 V_{UEC} -27.6).

The F_{CBL} estimates of the four Neanderthal specimens calculated using these RMA equations were significantly smaller than those of living human sample (Fig. 2, Mann-Whitney U test with Holm correction: p = 0.0055), while the V_{CBL} , V_{CBR} , or V_{TOT} estimates were not significantly. The F_{CBL} estimate of the Cro-Magnon 1 is small, narrowly within the range of the recent Modern Human variation. The V_{CBL} , V_{CBR} , V_{TOT} and F_{CBL} estimates of Skhul 5 and Qafzeh 9 crania were comparable to those of the living human sample. These results suggest that the Neanderthals had relatively (but not absolutely) smaller cerebella compared to the recent Modern Humans, while the earlier Middle Paleolithic *H. sapiens* represented by Skhul/Qafzeh shared relatively large cerebella with the recent Modern Humans.

The results of this study were partly compatible with Weaver (2001, 2005), which reported that the cerebella of Neanderthals and Cro-Magnon 1 were smaller than the means of the recent Modern Humans. However, our

 F_{CBL} estimates were not as extremely small as the F_{CBL} estimates derived from the data of Weaver (2001) (Fig. 2). The latter F_{CBL} estimates for the Neanderthal specimens (less than 0.8 on average) are considerably small among mammalian species (Clark et al. 2001). As we previously detailed (Kubo et al. 2014), the estimation method devised by Weaver (2001) has some unignorable problems. Therefore, we think that the cerebellar proportion within the total brain volume of Neanderthals is not so much small as previously reported.

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Fig. 1 Biplots of the volumes of the endocranial and brain parts obtained from the MRI data of the living human subjects. Left: the posterior cranial fossa (V_{PCF}) and cerebellum (V_{CBL}); Right: the upper endocranial parts (V_{UEC}) and cerebrum (V_{CBR}). Red solid lines represent the reduced major axis (RMA). Black solid lines represent the ordinary least squares (OLS) regression, and dotted and dashed lines are the 95 % confidence and prediction intervals of OLS regression.



Fig. 2 Estimates of 'volume fraction of cerebellum' (F_{CBL}), the proportion of the cerebellar volume within the total brain volume. The results of this study are shown in the left four columns. The comparative estimates calculated using the data from Weaver (2001) are shown in the right end column. The mean F_{CBL} of the recent Modern Human sample of this study is shown as a horizontal line, with comparison to that of Weaver (2001) represented by the open circle in the right end column.

Endocasts of Neanderthals and early Modern Humans: Virtual reconstruction and geometric morphometric analyses

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Introduction

In order to examine the possible differences in learning ability between Neanderthals and early Modern Humans in terms of the brain anatomy, original antemortem appearance of fossil crania that enclose the brains must be correctly restored. In the present study, we performed the virtual reconstructions of three Neanderthal crania, Amud 1, Gibraltar 1, and Chapelle-aux-Saints 1, and three early Modern Human crania, Qafzeh 9, Mladec 1, and Cro-Magnon1. The endocranial morphology was then analyzed using geometric morphometrics.

Materials and methods

In the case of Amud 1, we mathematically reassembled the fragments based on smoothness of the joints among fragments (Kikuchi and Ogihara 2013). As a result, smooth yet globally consistent assembly of the fragments of Amud 1 cranium became possible. However, the cranial base and endocranial surface of Amud 1 are largely missing or damaged. We therefore warped the Gibraltar 1 and La Chapelle-Aux-Saints 1 onto the Amud 1 crania to estimate the missing basicranial and damaged endocranial regions. In the case of Gibraltar 1, the La Chapelle-Aux-Saints 1 was warped to compensate for the missing regions, and vice versa in the case of La Chapelle-Aux-Saints 1. Reference Modern Human cranium was then warped onto the new reconstruction by iterative thinplate spline deformation to compensate for the missing parts and complete exo- and endocranial morphology was generated. The endocasts of the early Modern Humans were also generated in the same manner.

We then analyzed the morphological variability of the endocranial shape of the fossil skulls using landmarkbased geometric morphometrics. On the endocranial surface, a total of 16 anatomical landmarks were digitized. Equally-spaced points along the anterior boundary of the anterior cranial fossa and the inferior border of the groove for transverse sinus were also defined as landmarks (Morita et al. 2013). We define sliding semi-landmarks on the entire endocranial surface based on the shortest paths connecting pairs of anatomical landmarks and equally-spaced points along the midsagittal curve. Therefore, the variability in endocranial shape was examined based on a total of 171 anatomical and sliding semi-landmarks. We also included endocasts of the modern Japanese and European populations housed at Kyoto University and the University of Tokyo, respectively, for comparisons.

Results and discussion

Our results demonstrated that exo- and endocranial shapes are quantitatively different between Neanderthals and Modern Humans. Specifically, our geometric morphometric analyses revealed that Modern Human cranium shows relative enlargement of the cerebellar region, and relative expansion of the parietal area as suggested by other studies (Bruner et al. 2010; Gunz et al. 2010; Weaver 2005), possibly indicating that neuroanatomical organization may be different between the two species. Recent morphological studies on the pattern of endocranial

ontogeny of Neanderthals and Modern Humans suggested that relative expansion of the parietal and cerebellar regions are observed during the early postnatal period in Modern Humans so that the endocranium becomes more globular, but it is not the case in Neanderthal lineage (Gunz et al. 2012). Ontogenetic differences of the cranium and hence the brain between Neanderthals and early Modern Humans may thus differentiate developmental process of learning and social skills in early childhood, possibly leading to a critical difference in innate learning capacity between the two populations.

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Exploring the difference of brain anatomy and function between Neanderthals and Modern Humans: Neuroanatomical and functional neuroimaging approach

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Introduction

Conventionally, the differences in learning ability between H. sapiens and H. neanderthalensis have been evaluated in terms of skull shape. Such evaluations originally aimed at exploring the differences in activity of the brain contained in the skull. However, previous studies either created endocranial casts from reconstructed skulls to compare morphological features of the two species, or extrapolated differences in brain shape from skull landmarks for the discussion of functional distinctions. Most of the results were approximate volume or regional shape calculations based on cranial or skull shape, and no research efforts have been made to detect precise functional differences by superimposing cranial images of one species on those of the other within one framework. In addition, previous studies have not fully established the relationship between cranial morphology and the anatomical localization of brain function.

As magnetic resonance imaging (MRI) techniques have accelerated functional and anatomical brain imaging and the non-invasive direct measurement of living human brain activity (i.e. functional MRI) (Huttel et al. 2009), we are able to explore the functional localization of living humans (Friston 1997). During the last 30 years, methods used for the analysis of these data have also been developed. Here, we apply the anatomical transformation and standardization method used in functional brain imaging research to the morphological estimation of the cerebral parenchyma from reconstructed Neanderthal's skull. This approach will allow for high-precision reconstruction of the fossil brain, as well as a direct comparison of brain morphology between ancient and modern humans. Moreover, we refer the functional brain map in the Modern Humans, corresponding to the anatomically difference regions.

Framework of the analysis

The method of computational neuroanatomy is able to perform quantitative analysis of the biological shape of the brain (Ashburner and Friston 2007). This methodology has been developed in parallel with the analysis of functional brain mapping that measures living human brain activity (Huttel et al. 2009). The image registration technique uses spatial transformation of the images. Among the various spatial transformation techniques, a promising one that has recently been developed is the large deformation diffeomorphic metric mapping (LDDMM) approach. The LDDMM approach of high-dimensional non-linear transformation has several million degrees of freedom, as opposed to the one thousand in conventional non-linear transformation. Here, we employed DARTEL algorithm (Ashburner 2007), which is one of the LDDMM approach and is popular in the functional neuroimaging research field. As standardized stereotaxic space such as Montréal Neurological Institute (MNI) space is available using DARTEL (i.e. the image can be transformed into this space by adding a few steps), we can comparably easily integrate the estimation and creation of a Neanderthal 'fossil brain' with functional neuroimaging studies of Modern Humans.

The strategy is as follows: First, the skull shape of reconstructed computed tomography (CT) images of the Neanderthal is spatially deformed to the Modern Human skull shape segmented from the MRI image. The DARTEL algorithm is used to estimate a globally one-to-one smooth and continuous mapping between these skull shapes. Using the deformation or flow field in DARTEL, the Modern Human cerebral cortex segmented from the MR image is then inverse-transformed to construct the virtual Neanderthal's cortex, which is consequently best fitted to its skull shape. If this strategy goes well, we can use computational morphometry. We used deformation-based morphometry (DBM) (Ashburner et al. 1998; Chung et al. 2001; Chung et al. 2003) and automated anatomical labelling parcellation based morphometry. We used Amud 1, Giblarter 1, and La Chapelle-aux Saints 1CT images as the samples of Neanderthals, whereas more than 500 Modern Human MR images were used to direct comparison.

The important point of the functional neuroimaging research is that the results of the functional MRI only show the correlation between a specific task or task condition and the brain activity corresponding to the task, so that there is no causal relationship. We could not conclude the exact relationship between specific brain regions and mental processes or functions. Therefore, we have to perform similar functional MRI experiments and collect evidence about which part of the brain is truly correlated to the specific function. Meta-analysis is a tool for realizing this. The goal of the meta-analysis is to show that the consistently activated regions in a set of studies are related to the same psychological or mental process in a quantitative or statistical manner (Warger et al. 2007). Fortunately, almost all neuroimaging studies are spatially transformed to a standardized stereotaxic space. If we can select suitable functions of the human brain, the map corresponding to the differences in the cognitive abilities between *H. neanderthalensis* and *H. sapiens* can be elucidated. Here, we performed meta-analysis of several cognitive functions those might be related the difference between them.

Results and discussion

The results of DBM and AAL based morphometry showed that the parietal regions and hemispheres of cerebellum were larger in Modern Humans rather than in Neanderthals, whereas widespread occipital regions were larger in Neanderthals rather than in Modern Humans. Recently, many studies demonstrated that hemispheres of cerebellum play an important role for not only motor-related function but also higher cognition such as language, working memory, social abilities. Meta-analysis also showed that the lateral cerebellum is activated during social cognitions such as mentalizing, perspective taking tasks. Unlike anatomical complex neuronal network in the cerebrum, neural circuit of the cerebellum is rather simple. A functional unit contains 500 Purkinje cells and there are approximately 5,000 units in the Modern Human cerebellum. Recent functional neuroimaging studies demonstrated that the cerebellum has a variety of inner models that reproduce the dynamic essential properties of mental representations, which is deeply related to 'learning' (Ito 2008). As larger cerebellum is able to contain many inner models, Modern Humans can have more mental representations. In addition, lateral hemisphere of the cerebellum has rich connection to frontal and parietal regions of the cerebrum. The present results indicate that Modern Humans use brain more efficiently using larger cerebellum, which maybe one of the cause of replacement.

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The RNMH project: A summary

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The RNMH project posed an explicit research goal to investigate the replacement of Neanderthals by Modern Humans. This is to test the "learning hypothesis," a working hypothesis surmising that the replacement occurred as a result of differences in learning (abilities/strategies/behaviors) between the two populations. The project was launched in 2010 to run for five years. It involves six main groups of researchers representing prehistoric archaeology, cultural anthropology, theoretical anthropology, environmental science, physical anthropology, and neuroscience. The researchers participating in this project number almost 70, including those specialized in other related disciplines. While the research is expected to continue into the next stage, the targets and achievements of the project thus far are summarized here for evaluation on the occasion of this international meeting.

Neanderthals and Modern Humans: The contributions of the RNMH project

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Originally Neanderthals were a European population that emerged some 400-200,000 years ago from an earlier population. They were successful in surviving through several glacial periods whether across temperate or Mediterranean Europe. They were also effective travellers who migrated eastwards reaching western and central Asia. They formed a meta-population archaeologically represented by fossil remains and numerous sites and assemblages. Few fossils produced the aDNA information indicating a degree of homogeneity among the people. The archaeological remains of their past life ways exposed a few burials and isolated bones and teeth in many sites, as well as food refuse (including animal bones and as yet rare plant remains, often due to poor preservation). Well preserved anthropogenic deposits, such as in the Mediterranean basin, hearths were uncovered as well as middens suggesting acts of cleaning the living surfaces. Climatic fluctuations had only minimal effects and excavated sties in northern latitudes indicate their special physical adaptations that apparently contributed particular genes to Modern Humans with whom they interbred in various locations.

We are able to trace the presence, movements and choices of sites of Neanderthal groups through the analysis of the abundant lithic assemblages. Such geographic tracing is done through the detailed reconstructions of various operational sequences that begins from the search and choice of raw materials, the preliminary preparation of the nodules, the shaping of the cores, detachment of blanks, choice of the selected few for use and/or further retouching, and discard. The rejected cores that were 'exhausted' in the eyes of the local knappers and thus considered useless, could have serve as toolstones the children of the group. We note that the assumption based on the experience of flint knappers is that teaching the skills of making stone tools begins at an early age. The process could have been similar to teaching children when they grow up how to use chopsticks as the parents speak and demonstrate the gestures in their own language. Similarly kids could learn how to make stone tools through observations and imitation, following instructions and encouragements by the adults. In brief, the education at an early age is the key for figuring the use of each operational sequence. This was the main target of the RNMH project, directed by Prof. T. Akazawa and his associates.

At the time when the western world was discussing and debating issues such as the chronology of Neanderthals' sites, the markers of their cultures, their diets (either mostly based on meat or just mixed), issues of longevity, health, behavior under stress conditions and their cognitive development, the RNMH project took essentially a different direction. Issues of the evolution of the brain, differences between human populations, social relationships and basic were not abandoned. But in my view, the main contribution of this project was by raising the place of learning, teaching and transmission among past societies to the top of the list of our concerns in understanding the behavior of humans during the Paleolithic. Thus, not only Neanderthals were examined but also Modern Humans. And because the main archaeological finds are stone tools and animal bones, to which we can now add the study of microscopic residues, I personally felt that the RNMH project is heading in the right direction. However, as I was originally trained by the late F. Bordes and was already biased thinking that different groups within the same meta-population would have their own set of operational sequences for the production of stone tools employed for various tasks. Microwear and edge damage demonstrate that various tool types were employed for the same activities (e.g., butchering, whittling, wood working, etc.). Thus the RNMH project attracted my attention.

Here I would like to mention that interpreting the known Paleolithic knapping techniques, assemblage composition and tool types are today not exclusively the domains of archaeologists. The reports produced by archaeologists who painstakingly classify all the uncovered elements collected during the course of surveys and excavations, became sources for ideas and interpretations by psychologists, brain scientists, researchers of cognitive evolution and more. Lively discussions concerning the interpretation of "modern behavior" of particular prehistoric cultural contexts continued although it became clear in recent years that humans at different times in various regions produced particular and sometimes unique, material culture elements. In some cases "modern behavior" was identified by prevalence of blade production, body decorations (beads and pendants made of different raw material), rock art, intra-caves murals and open-air sites engravings, as well as mobile imagery (e.g., figurines, decorated organically made artifacts). But in more than one region many of these cultural elements are missing but the people themselves as shown by the morphology of their skulls, were identified as 'modern'. Even the efforts to trace the presence of language and symbolic behavior as currently incorporated within the *enhanced working memory*, was proven to be a tough endeavor.

Indeed, the RNMH project directed a portion of the time and funds into the investigations of social learning, teaching, and creativity among children including hunting and gathering societies. Recording the differences and similarities among individuals, and limitations to human behaviors imposed by social learning were also researched. As expected, some needed testing was carried out among hunting and gathering societies. The insights gained from analyzing teaching and learning among several groups of children of foragers concerning their activities are used in order to consider their resilience, and how they face demanding situations. These studies corroborate what is achieved through the investigations of other Modern Humans when they asked to face variable social situations or in testing their foresights. The cases studied and reported today are based on Modern Human behavior but several evolutionary hypotheses take into account the contributions from primate behavior, but unfortunately we miss the behaviors of *Homo erectus* populations. Thus the challenge to find if there were fundamental differences among 'cultural learning's' between early Modern Humans and Neanderthals' longer history is a daunting task. The debate often centers on 'problem-solving' and 'creativity' between these two meta-populations. Various analyses demonstrate a greater degree of conservatism among the Neanderthals possibly due to the fragmentation of their Eurasian populations. In spite of being successful foragers and migrants they were taken over by Modern Humans. It seems that the an increased degree of social flexibility, improved foresights, better means of communication, and perhaps having a more efficient technology, facilitated Modern Humans to take over this the Eurasian continent within no more than 10,000 years and perhaps much less.

Poster Presentations

Past and present research on the Middle and Upper Paleolithic of Uzbekistan

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Researchers' great interest in studying the Paleolithic of Uzbekistan is based on their belief that this region represents a contact zone, or rather some kind of a "transit place" for ancient human populations occupying East and West Asia and other parts of the Paleolithic world. To date, Paleolithic research of the region has yielded a sufficient amount of archaeological materials. Analysis of this record allows us to track the evolution of the most primitive populations and their cultures and raise questions on the origins of Paleolithic communities living in the territory of what is now modern Uzbekistan.

The first discoveries of Paleolithic cultural remains in Uzbekistan were made in the 1930s during fieldwork by geologists and archaeologists at a number of locations. Between 1931 and 1934, G. V. Parfyonov found a series of caves and rockshelters; he partially excavated Machay Cave in the Shirabaddarya Valley (Surkhan-Darya region). This site was investigated by U. Islamov again in the 1970s, when he revealed stone and bone tools as well as human remains of the Mesolithic period.

The archaeological records from the Uchtutin Bukhara region comprise the most complete chronological sequence starting from the Lower Paleolithic period. Long-term research there has yielded abundant materials from the Acheulian, Mousterian, Upper Paleolithic, and Neolithic periods. In the Akhangaron River valley of the Tashkent region is the unique multi-level Paleolithic site of Kulbulak, the focus of long-term research since 1963. Rough stone tools such as cores and massive flakes from slate and flint were found there. In addition, Kulbulak remains the only known Mousterian site in the region.

The main level of the multi-level cave of Sel-Ungur (Fig. 1) in the Fergana Valley (700–500 ky BP) also belongs to the Lower Paleolithic. This site was for many years studied by the academician U. Islamov. Excavations there yielded disc-shaped cores, unifaces and bifaces, broad flakes, scrapers, knives, and choppers made on pebbles. Moreover, sensational finds included teeth, a humerus, and the back part of a skull of the anthropoid called "Fergantrop" (Fig. 6).

A group of sites from the Mousterian period were found in the Surkhan-Darya region, Chirchik-Akhangara Valley, Bostanlyk area (Tashkent region), and the Fergana Valley. These groups differ regarding the nature of processing stone and the composition of stone processing tools. One of the most significant sites is Teshiktash Cave (Fig. 2), discovered by L. P. Okladnikov in 1938. He found not only Mousterian stone tools, but the first remains of a Neanderthal child burial ever recorded in Central Asia. Based on the materials recovered, a number of features of this primitive people's life were established. Excavation of the site revealed the bones of such animals as goat, deer, and bear. Stone tools were made on-site from quartz, quartzite, jasper, or siliceous limestone. Tool production technology is typical for the Mousterian, as seen in a disc-shaped core. The main tools are scrapers and small chisels. The most important discovery was the burial containing the remains of a boy; this Neanderthal individual's shape was reconstructe by the famous anthropologist and archaeologist named M. M. Gerasimov. The grave contained mountain goat horns, reflecting the origin of Neanderthal cult representations.

In 1939, an Upper Paleolithic site in the city park area of Samarkand was opened by N. G. Kharlamov. It was

later investigated by M. V. Voyevodsky. Excavations were renewed in 1958 by D. N. Lev, and then continued by M. D. Dzhurakulov. In 1960 and 1964, H. K. Nasretdinov found and excavated the Late Paleolithic Ak-Tash Cave. Numerous stone artifacts of the Mousterian, Upper Paleolithic, and Mesolithic were obtained from the site of Bozsu 1-2. The Mousterian localities of Bozsu 3-5 and Zakh were subsequently discovered.

One of the first Mousterian finds in the Tashkent region was in 1942 by R. V. Smirnov. In 1958, P. T. Konoplya discovered the Mousterian site Kuprikbosh. The cave of Hodjakent-1 was excavated in 1958–1959 under the direction of A. P. Okladnikova, and Hodjakent 2 was studied by H. Nasretdinov.

R. K. Suleymanov studied one of the richest cave sites, Obi Rakhmat (Fig. 3), which holds a special place among Mousterian sites of the Tashkent region. This is because its cultural layers contain many thousands of stone artifacts in-situ (Fig. 4). For this region, this site is unique because most Paleolithic sites have disturbed stratigraphic contexts or contain small lithic collections. Throughout the second half of the 20th and beginning of the 21st centuries, analyses of the Obi Rakhmat collections have revealed several cultural and chronological phases of development of the regional Paleolithic. Thus, depending on the excavation methods and analysis of lithic materials by researchers, various conclusions have been drawn regarding the chronological and cultural interpretations of complexes from this site.

In Layer 16 of Obi Rakhmat, six teeth and about 150 small skull fragments (Fig. 5) belonging to a child aged 9–12 years were found in 2003. The scholars M. Glantz, B. Viola, and T. Chikisheva believe that the small skull fragments have no diagnostic characteristics, indicating the duplication of bones. Regarding the teeth, their large size (characteristic of Neanderthals or a robust *Homo sapiens*) and root development provide no information on the types of hominin. Skull fragments reflect a morphological structure more similar to a Modern Human, with a big parietal lobe uncharacteristic for Neanderthals. The temporal bone also looks modern but the inner ear labyrinth has no clear morphology. Therefore, there is a mosaic of Modern and Neanderthal types.

In 2000, the southern slope of the Karatyubinsk massif (main watershed valleys of the Kashkadarya and Zarafshan rivers) was examined by the archaeologist R. K. Suleymanov. He was in the Ayakchisaya Valley, where the Middle Paleolithic site of Angilak Cave is located. Under the guidance of R. K. Suleymanov and M. Glantz, archaeological work was conducted between 2001 and 2004, during which it was revealed that the stone industries of Angilak were similar in technology and typology to those of Kuturbulak and Amankutan caves. However, they differ in terms of their strongly amorphous nature and the small sizes of cores, chips, and tools. Excavations at this site were resumed in 2013–2014 by the State Museum of History of Uzbekistan and the University Museum of the University of Tokyo under the guidance of R. K. Suleymanov, O. Aripdjanov, and Y. Nishiaki.

Recent studies of Middle and Upper Paleolithic complexes in Uzbekistan allowed us to specify characteristics of Paleolithic complexes from certain sites, and to revise the general provisions concerning the Upper Paleolithic of the region. This region became a zone through which humans moved in later times, based on finds from numerous Acheulean and Mousterian sites. All analyzed industries are characterized by a clearly established combination of Middle and Upper Paleolithic attributes.



Fig. 1 Archaeological expedition at the entrance to Selungur Cave (Lower Paleolithic), 1985.



Fig. 2 General view of Teshiktash Cave (Middle Paleolithic), Surkhandarya region.



Fig. 3 General view of Obi Rakhmat Cave, Tashkent region.



Fig. 4 Stone artifacts of Obi Rakhmat (Middle-Upper Paleolithic transitional period). Tashkent region.



Fig. 5 Human fossils of the Middle Paleolithic from Obi Rahmat, Tashkent region.

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The Neanderthal occupations at Dederiyeh Cave, Syria

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The Middle Palaeolithic sequence of Dederiyeh Cave, northwest Syria, is unique in its association with a series of Neanderthal fossil remains from stratified contexts (Akazawa and Muhesen 2002; Nishiaki et al. 2011). One particular area (*Chimney area*) of this large cave attests to the continuous occupations of Neanderthals during the late Levantine Mousterian (ca. 70–50 ka), providing an opportunity to investigate chronological changes in Neanderthal behaviors. With reference to lithic assemblages and other evidence from this area, excavated between 1989 and 2002, we address how Neanderthal settlement patterns and population size might have changed.

The available data suggest a significant increase in occupational intensity during this time period (Nishiaki et al. 2012). This is demonstrated by a rapid increase in the number and size of fire hearths and a remarkable increase in lithic artifacts per volume of sediment (m3) through time. Furthermore, technological and typological traits thought to indicate more sedentary occupations also became more remarkable in the upper layers (see Parry and Kelly 1987). They include the higher frequency of expedient tools at the expense of standardized tools such as Levallois points and side scrapers, and the more common practice of expedient core reduction rather than careful core preparation.

These changes collectively point to a shift from a more ephemeral to more prolonged use of the cave. In other words, the base-camp character of the Dederiyeh Cave became more conspicuous in upper layers. This can be interpreted as responses to the increasingly favorable environmental conditions later in the Mousterian sequence at Dederiyeh Cave: wild boar, aurochs, and deer indicative of temperate and humid environments appeared in faunal assemblages of the upper layers, replacing goat remains that indicate colder and drier environments (Griggo 2002). Evidence in the sedimentological records of decreasing soil inflow from outside the cave has also been interpreted to show increased vegetation due to increased precipitation (Oguchi and Fujimoto 2002).

Research in the southern Levant highlighted a comparable trend for the entire Levantine Mousterian sequence, in which occupations intensified from the middle Levantine Mousterian onwards (ca. 130 ka). This trend has been interpreted to indicate a residential shift from a more mobile to a more sedentary, territorial residential pattern due to population increase (Hovers and Belfer-Cohen 2013). In this vein, findings from Dederiyeh might suggest that the trend, i.e., demographic increase, continued throughout the late Levantine Mousterian. If so, future research can utilize the stratified lithic assemblages from Dederiyeh to test theoretical premises often predicted on the relationship between demography and cultural evolution among human societies; for example, whether and how a positive correlation between population increase and cultural complexity also existed among Neanderthal societies.

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Fig. 1 Mousterian tools and debitage from the upper layers of the chimney area.



Fig. 2 Mousterian tools and debitage from the lower layers of the chimney area.

Poster Presentations

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The emergence of the Upper Palaeolithic in the Japanese archipelago

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The replacement of Neanderthals by Modern Humans can be explained not only by the differences in the evolutionary history of human populations but also by the differences in the nature of society and culture that they have experienced. It is important to investigate the causes of the replacement from such a viewpoint as well. When Neanderthals were replaced by Modern Humans, various cultural/social changes occurred in Eurasia. Given these archaeological changes, it is necessary to examine each of the regionally diverse cases. In this perspective I discuss how Upper Palaeolithic cultures formed in the Japanese archipelago.

When we discuss the emergence of the Upper Palaeolithic in the Japanese archipelago, it is important to examine three aspects: stratigraphy, dating, and stone tool types. The earliest Upper Palaeolithic assemblages are found in the central part of Honshu, the mainland of Japan. For example, the assemblages in the Ashitaka-Hakone area, dated to 38-36ka BP, indicate that the earliest inhabitants settled into the Japanese archipelago by at least 40ka.

These early assemblages are divided into several industries. One is the small flake industry which is characterized by light retouched flakes, scrapers, and drills. There are few formal tools in this industry. The second is the denticulate industry characterized by denticulates on flakes, picks, and scrapers with inverse retouch. The third is the pebble tool industry or heavy duty tool industry characterized by choppers, chopping tools, "hand axes". Their chronological sequence or functional relationship is currently unclear due to the scarcity of relevant records. Importantly, these early industries do not include blade technology or polishing technology, which subsequently characterize the Upper Palaeolithic period of Japan.

Blade technology appears for the first time in Japan around 36-35ka. In Happusan II site, Nagano Prefecture, blades are detached from unidirectional narrow faceted cores. The blade blanks are then used for the production of tools including pointed blade, burins, and scrapers. The assemblage has another distinctive feature of the bladelet production from core edge flakes or flake cores. In this initial phase of the blade/bladelet technology, trapezes and edge ground axes also emerged. Because trapezes or edge ground axes did not develop in China, Korean peninsula, or Siberia, these lithic technologies probably emerged independently in the Japanese archipelago. The trapezes may have derived from preceding small flake industry while it is difficult to trace the origin of the edge ground axes. The form of the edge ground axe is similar to large pointed tools, classified as "hand axes", in Kanadori site, and it is technologically similar to chopper/chopping tools using flat pebble stones. The use-wear analysis shows that the edge-ground axes have been used for cutting trees and modifying wood. Thus, it may have derived from previous large cutting tools. However, it is impossible to trace the origin of polishing technology used for the production of this lithic type.

During 34ka-32ka, a very distinctive settlement organization, named "Kanjou burokku", appeared throughout Honshu, the main island of Japan. This consists of several lithic clusters arranged in a circular pattern, which appears to have occurred exceptionally in the Japanese archipelago. Although this settlement type used to be considered as representing aggregation sites for the big game hunting, it provided at least opportunities for the exchange of information among the groups that gathered at the site. Such social networks possibly explain the emergence of standardized tools, such as blades, trapezes, and edge ground axes as well as their regional

diversification.

The following summarizes the above descriptions regarding the emergence of the Upper Palaeolithic in the Japanese archipelago.

(1) Widely accepted archaeological records indicating the colonization of the Japanese archipelago date after 40ka. The earliest industries basically consist of the small flake industry and the heavy duty tool industry. Because these lithic technologies are similar to the Early Palaeolithic industry in eastern Eurasia, it would be suggested that the lithic industry before blade technology in Japan can be related to the east Eurasian lithic industry.

(2) Major changes have appeared after 36ka. One is the formation of trapeze industry. This industry was fully equipped with various types of trapezes. This trapeze industry may have derived from the preceding small flake and denticulate industries. Edge ground axes also appeared.

(3) Another change is the formation of blade technology. Large blades and bladelets were produced from narrow faceted cores, and the blade blanks were then modified into pointed blades, scrapers, and burins. There are two different views regarding the origins of the blade technology in Japan. One suggests that the blade technology was introduced to the Japanese archipelago from adjacent areas, such as Siberia and China, whereas the other argues that the blade technology developed independently in Japan from previous lithic industries. The former scenario currently appears to have gained more supportive records.

(4) After 34ka, the blade technology became more standardized. Blades of this phase are manufactured from exotic raw materials of higher quality than those produced from local materials. The blade technology of this phase is characterized by prismatic cores and core debitage such as core rejuvenation flakes, striking-platform rejuvenation flakes, surface rejuvenation flakes, and core edge trimming chips. Bladelets are detached from cores on blades and piece esquillees. In this phase, some stone tool types became more standardized. They are produced from particular raw material types or blank types.

(5) Archaeological evidence for symbolic behaviors are scarce until 30ka. It has become prevalent since the LGM period in Japan.

In this paper, the beginning of the Upper Palaeolithic in Japan is defined by the emergence of trapezes and edge ground axes. Therefore, preceding lithic industries should be separated from the Upper Palaeolithic. In eastern Eurasia, the Palaeolithic culture is usually divided into two periods, the Early and Late (Upper) Palaeolithic, instead of the tripartite periodization in western Eurasia. Based on the two-period system, the lithic industries before blade and trapeze assemblages are grouped together in the Early Palaeolithic. However, these industries are few and their chronological or functional relationship is unclear. We also need to carefully evaluate their culture-historical links to the subsequent blade and trapeze industries. In addition, even if the lithic industries before the trapeze or blade technologies are included in the Early Palaeolithic, it does not mean that their makers are not Homo sapiens.

In the case of the Japanese archipelago, the transition to the Upper Palaeolithic is regionally diverse. This paper focused on the records from the central part of Honshu, where blade technology emerged relatively early in Japan. In this region, cultural elements that have been considered part of "Modern Human behavior" appeared gradually, indicating that the Upper Palaeolithic cultures did not spread out at once. Lastly, it is important in future to examine regionally diverse processes towards the Upper Palaeolithic in the Japanese archipelago as it is geographically extensive and diverse in the north-south direction.

On the mechanics of the spear thrower

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Introduction

Between about 50,000 and 40,000 years ago, Neanderthals in Europe were replaced by anatomically Modern Humans. Various explanations have been offered for processes leading to the replacement of Neanderthals by Modern Humans (RNMH). One argument has posited that Modern Humans developed complex projectile weapons, such as the spear thrower, before the RNMH, and that these innovative technologies improved hunting efficiency and broadened the range of prey species availability. (The spear thrower is a tool that increases the effectiveness of spear throwing, and consists of a shaft with a hook or socket at the end that propels the tail of the spear.) To properly evaluate this argument, empirical data are needed on spear throwing with a spear thrower.

In the project entitled "Reconstruction of Hunting Behavior with Projectile Weapons in Neanderthals and Early Modern Humans Based on Differences in Skeletal Morphology", I have been making experimental studies 1) to show the respective advantages of using the hand-cast spear and spear thrower in hunting and 2) to estimate spear-throwing ability in Neanderthals and early Modern Humans. In this meeting, I report the results of two experiments concerning the mechanics of the spear thrower.

Experiment 1

The purpose of Experiment 1 was to investigate similarities and differences in upper-limb kinematics between spear throwing with a spear thrower and by hand alone (Fig. 1). Two healthy subjects with no special experience in throwing spear-like objects participated in this experiment. The experiment was conducted outdoors at Osaka University. The subjects were instructed both to throw a spear as quickly as possible and to aim at a stationary circular target (0.8 m diameter) placed 8 m away. Throws were videotaped using three digital camcorders at a sampling rate of 240 Hz. The bony landmarks and proximal end of the spear were digitized using Frame-DIAS IV motion analysis software, and their three-dimensional coordinates were obtained using the direct linear transformation technique. The velocities of the digitized points and the joint angles were compared between the two throwing methods. The experiment quantitatively showed similarities and differences in upper-limb kinematics between spear throwing with a spear thrower and by hand alone, and reveals an aspect of the mechanics of the spear thrower.

Experiment 2

The purpose of Experiment 2 was to examine the kinetic energy transfer from the body to the spear. Ten healthy subjects with no special experience in throwing spear-like objects participated in this experiment, and the experiment was conducted outdoors at Osaka University. The subjects performed six different tasks: 1) throwing spears horizontally with a spear thrower; 2) throwing spears horizontally by hand alone; 3) throwing spears obliquely with a spear thrower; 4) throwing spears obliquely by hand alone; 5) throwing spears with a spear thrower while sitting; and 6) throwing spears by hand alone while sitting. Spear and body movements during throwing were analyzed using a video-based motion-capture system (Frame-DIAS IV). The results showed

that the use of a spear thrower generally increased the spear release velocity and the kinetic energy transfer from the body to the spear. How the characteristics of the spear thrower shown in this study work in a real hunting situation are discussed.



Fig. 1 Spear throwing with a spear thrower (a) and by hand alone (b).

Mediated action through art works among children: Similarities and differences between traditional and modern society

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The concept of mediated action was originally advocated by Vygotsky (1934) from a sociocultural perspective. That is, he insisted that there were three basic themes: 1) reliance on genetic and or developmental analysis, 2) the claim that higher mental functioning in the individual derives from social life, 3) the claim that human action, on both the social and individual aspects, is mediated by tools and signs. Although these three themes are closely intertwined in his theory, in this study, I will focus on the third one. Mediated action carried out by means of psychological tools (signs), such as languages, maps, calculation system, art and so on, is peculiar to human beings. In particular, art works, which were chosen as media here, involve both concrete materials such as paint and canvas in the outer world and psychological meaning such as desire and phantasy in the inner world. That is, art is one of the "transitional objects" (Winnicott 1973), which functions as a bridge between reality and mind, and that eventually can be a representation with the effect of catharsis and sublimation (Freud 1915) and symbols with transcendent function (Jung 1928).

The purpose of this study is exploring mediated action among children through art works, which might demonstrate that human beings unique and effective in responding to the environment. I also find there is a difference between traditional and modern society in terms of mediated action. As for the procedure, I applied drawing and collage to Baka Pygmy children in Cameroon, as well as to modern society children in Japan and the USA. I organized small groups, which were composed of developmental stage such as early childhood (5-6yr.), middle childhood (10yr.) and adolescence (12yr. over), separate sexes, and age and sex mixed. Each group consisted of 2-6 members. The instruction was "draw what you ate yesterday", "draw yourself at that time" and "draw the person you ate with". The collage was administered with the instruction of "regard this paper as your house, and then cut and paste what you want here in your house out of these photos".

The results supported the previous research, in which "socialization practices in some nonwestern cultures involve much less reliance on verbal communication than is typical for western children" (Rogoff 1990). Instead, nonwestern children had visual spatial memory tasks involving eyesight and hearing. Actually, in this study Baka children did not talk so much but were sensitive and responded to each other, using pointing, gazing and murmuring. This nonverbal (preverbal) communication was observed for them. For example, in the collage work, the children were required to use scissors and glue. One of them was not able to use scissors and looked up to an older boy. Then the older one understood the implication from his facial expression and cut materials instead of him without words (Fig. 1). On the contrary, in the group of 5 years old boys in Japan, one boy asked another member how to paste, and he responded with words, helping him. On the drawing, the media of sheet of paper and crayon might facilitate Baka children to express their fun time with a football, important legs for forest life as well as wild food. Although these members did not discuss the drawing with each other, all of the exposed images were similar (Fig. 2). On the other hand, in a young group in Japan, two of them drew "spaghetti, I, mom, dad and sister", while talking to decide what they should draw (Fig. 3). Thus, although there was difference of communication style between traditional and modern society, the media can facilitate children to cooperate with others.

In conclusion, cooperation among children was observed through the mediated action, such as "an innate,

species-specific capacity for shared intentionality" (Tomasello 2009), and moreover, "an innate, species-specific combinational capacity" (Spelke 2009).

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Fig. 1 Baka boy's group: Football, vehicles, animals.



Fig. 2 Baka girl's group: Humans with exaggerated legs, footballs, spears, fishes, chickens, potatos.



Fig. 3 Japanese 5 yr. children: Spaghetti, I, mom, dad, sister, grapes, salads.

Cognitive development of Baka Pygmy children growing up in modern hunter-gatherer society

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Cognitive development of the children in growing up in hunter-gatherer society

Homo sapiens had to adapt to their environment. To do that, we have developed more complex knowledge and behavior. Development of more complex knowledge and behavior is dependent on dynamic interplay among biological, cognitive, and social system dimensions (Davis and Bedore 2013). For example, in language learning, infants would do differentiate between salient and non-essential incoming stimuli, gain and store more diverse goal-directed movements related to their ambient language requirement by infant-internal interconnections between physical systems of body and social interaction capacities tuned by input of ambient language (Davis and Bedore 2013).

The children who are grown up in hunter-gatherer society would develop their cognitive capacity to continue to maintain the life of their society. In this paper, the author investigated the distinctiveness of cognitive development in Baka children who growing up in modern hunter-gatherer society.

Repetitive production

In Fig. 1 overlapping circles indicate physical capacities involved in acquisition of knowledge structures. For example, that forms the basis of fully realized phonological system (Davis and Bedore 2013). Each relies on an overall general capability for pattern formation. Pattern formation would be tuned and refined (it is the cognitive process) by extrinsic context in early infancy by development of joint attention, intention reading, and turn taking. Refining patterns affect the productions.

Homo sapiens adapted to their environment by tuning and refining with cognition and repetitive production. Neanderthals also might have used this process. The capacity of imagination might develop on the base of tuning, refining and repetitive production. Those processes would be noted for early human adaptations.

The process of tuning and refining would affect sharing intentionality

The capacity of infants is to be required for their future living. In Baka infants who are grown up in modern hunter-gatherer society, about 9 month or so, infant would begin to tune to ambient inputs and begin to incorporate into them (Koyama 2014). Maybe joint attentional behaviors led to activate the tuning process. It was reflected in children's social referencing behavior indicating sharing intentionality of others.

The author investigated social referencing behaviors of 27 Baka children during performing object-construction with wooden blocks in accordance with model which a stranger made. Their parents permitted to the participation in this study. Children were introduced to the play situation with the author by an assistant who was a Japanese anthropologist being acquainted with Baka people participating this study. He could speak Baka language well. And he was there in the situations a child played with the author. During that play children engaged in constructing object with wooden blocks matching with a model made by the author in the face to face

situation. The verbal instructions to the children were translated into Baka language.

Fig. 2 indicated the mean frequencies of children's social referencing to the author in each age group. Table 1 showed SD of each age group. It was thought that results showed sharing with intentionality of others during construction with brocks in accordance with model that adults made. At just about 4 years of age, social referencing to author during children's constructing (in process) and performing goal directed acts (completed) checking form the viewpoint of others increased. Those behaviors showed sharing intentionality with others in construction of objects. We need to investigate the relationship between these behaviors and children's flexible adaptation from about 4-year-old.

Their capacity of abstraction

As I reported in previously, Baka children showed much flexibility on object substitution in their play and matching up geometric figures (Koyama 2013, 2014). Matching up geometric figures indicated their capacity of abstraction of shapes. As for those developments, variation was found (Koyama 2014). The capacity of abstraction would develop gradually from 3 year-olds to 5 years-olds (Table 1).

Entering into languages in figures: Baka children were in oral language culture

Nelson (2014) pointed that in cultural evolution there were three stages in human development. The first one is mimetic culture stage. Chimpanzees might be in this stage. Next is oral language culture stage. Nelson (2014) emphasized narratives were main mythology for children. Third is the stage of language in figures. Baka children were in oral language culture, and they began to enter into language in figures culture and they showed intuition to perception of figures (Koyama 2012). They could collect and match one picture with a similar figure that was depicted objects they had not seen and gone through that. But using figures in their symbolic play were seldom observed in my research.

Distinctiveness in their pretend play

The copy of daily experiences is noticed in Baka children's play. The author hypothesizes that human imagination develops on the base of anchoring to their real world and reconstructing daily experiences and our knowledge (decoupling) (Leslie 1987; Koyama 2013). Those processes were observed in Baka children's pretended play.

Baka children shared object substitutions with other children (Koyama 2013). Production with objects in their symbolic play based on copying of their experiences and older people's daily activities in daily hunter-gathering life was observed. That plays were cooperative with other children. From about two years old, they simulated older people's daily activities in those play. Those simulations were noticed. In addition to that, tuning and refining based on previous repetitive production and objects pragmatism were showed in those plays. And this would be noted from the view point of embodied cognition.

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Fig. 1 Physical capacities involved in acquisition of knowledge structures.



Fig. 2 Mean of frequencies of social referencing in Baka children while they were engaged in constructing object with wooden blocks.

Table 1 SD of each age group.

	in process	completeds	
Зу	1.03	1.48	
4y	4.47	1.2	
5y	0.79	0.49	

Table 2 Percentage of choosing same figure in type I (Koyama 2014).

	circle	triangle	square	semicircular	cross
3 year olds	30.0	50.0	50.0	50.0	60.0
4 year olds	50.0	70.0	70.0	70.0	80.0
5 year olds	85.7	71.4	71.4	71.4	71.4

Learning process on the skills of reading nature

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The foraging strategy of the Neanderthals is supposed to have centered around large mammals. On the other hand, the tool manufacturing industry of early Modern Humans have shown a clear trend to the diversification of food items (Fa et al. 2013; Kuhn and Stiner 2006; Richards and Trinkaus 2009; Snodgrass and Leonard 2009), which shows the development of cognitive capacity on their environment and food resources, i.e., nature. The innovation of the skills of 'reading nature' might have occurred in Modern Humans (Shipman 2011). To understand the characteristics of learning the skills of reading nature, this study focuses on learning process of hunting skills among children of the San, hunter-gatherers in the Kalahari Desert of southern Africa.

San are well-known as large game hunters shooting with a bow and arrow, and/or a spear. However, they get meat animals, not only large but also middle and small size animals and birds, by various methods, especially by snares. Traps provide a stable supply of animal meat. I collected information about traps. The results are;

1. They have many kinds of traps for large game such as gemsbok and kudu, middle size mammals such as duiker and steenbok, small mammal such as mongoose and ground squirrel, middle and large size birds such as ostrich, kori bustard and korhaan, and small birds.

2. Not only men but also women use snares especially for middle and large sized birds.

3. Boys play with trapping small animals.

Focusing on boys hunting, they use snares for small animals and middle size birds, a toy bow and arrow for birds and lizards, a slingshot for small animals, birds and lizards, and traps with waylay for catching small birds. On the other side, girls learn how to set snares for birds when they go gathering with women. To get technic for traps children must know the behavior of animal and which vegetables animal eat. They learn 'skills of reading nature' by hunting.

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Fertility and population dynamics of Baka hunter-gatherers in southeast Cameroon

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Cognitive development of the children in growing up in hunter-gatherer society

Demographic parameters adequately indicate the health status of a small population. Until the 1980s, studies of Pygmy populations described low viability and very short life expectancies (mid-20s). The Baka are a group of pygmy hunter-gatherers living in the central African rainforest whose habitat extends mainly over southeastern Cameroon. In the last few decades, Baka society has shifted to settlements; communities relying entirely on hunting and gathering are disappearing. Permanent villages along roads increase access to public health centers. There now exists intergenerational variation among their demographic characteristics. This study aimed, namely, to reveal the fertility and population dynamics of current Baka hunter-gatherers and, to estimate the transition of their fertility over the generations.

Subjects and methods

Census, birth, death, and migration data for four Baka villages located in the East Province of Cameroon were collected three times from February to March of 2011, 2012, and 2013. Personal interviews covering names, clans, marital statuses, and births of children were conducted with all residents. Their ages were estimated in one-year ranges for children and five-year ranges for adults. Genealogical data was collected from 66 women who married village residents. There were a total of 295 women who had completed reproduction in reconstituted pedigree. Following Ohtsuka (1990), they were categorized into four generational groups: (A) not all female offspring have married; (B) All female offspring have married; (C) all female offspring have completed reproduction; (D) All female offspring of all female offspring have married. The daughter-mother ratio, (DMR), the ratio of the number of married female children to the number of mothers, was calculated for each group.

Results and discussion

Fig. 1 shows the population structure in 2011; the population was 611 and the sex ratio was 107.8. The median age was estimated at 19.1 years, and 42.6% of population was under 15 years indicating that the Baka population was relatively young. The number of births exceeded the number of deaths during the observation periods; thus, the population naturally increased. The crude birth rates were 39.2 for 2011-2012 and 42.5 for 2012-2013. Fig. 2 shows the distribution of the 295 women by number of offspring. The mean completed parity was 5.03 ± 3.05 . Baka population had the same level of fertility as other African hunter-gatherers as seen in Table 1. Table 2 contains DMR and estimated Lotka rate (*P*) for each generational group. Although there is no remarkable difference between the generational groups, nor an increasing trend, the DMR of the this population is relatively high.

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Fig. 1 Population structure of target villages in 2011.





Table 1 The fertility among hunter-gatherer societies.

group	Fertility	Study area	Reference
Baka	5.03	Cameroon, rainforest	present study
Aka	5.04	Central African Republic, rainforest	Hewlett, 1978
!Kung	4.69	Namibia, Kalahari desert	Howell, 1979
Agta	6.53	Philippine, rainforest	Goodman et al., 1985
Ache	8.03	Paraguay, rainforest	Hill and Hurtado, 1996

Table 2 Daughter-Mother Ratio (DMR) and estimated Lotka rate (P) by mother's age groups.

		No. of married children			P at mean child bearing age		
group	N	Male	Female	DMR	20	25	
В	88	106	235	2.670	0.050	0.040	
С	37	62	83	2.243	0.041	0.033	
D	26	38	81	3.115	0.058	0.047	
B-D	151	206	399	2.642	0.050	0.040	

The formation of cooperative society initiates the evolution of risk-taking innovative behaviors

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Introduction

Modern Humans are outstanding in innovative behaviors among all living animals. How did highly innovative behaviors evolved only in humans? In other words, why did the other primates not acquire such behaviors? This is one of the essential questions for understanding the evolution of human learning strategy and ability. Many researchers have theoretically studied cultural evolution to clarify what factors lead highly developed cultures in humans (Reviewed in Aoki and Feldman 2014). These previous theoretical studies have pointed out a paradox that, in the presence of imitation (social learning) strategy, risk-taking innovation behaviors do not survive and thus cultural evolution is not promoted. Therefore, some model will be required to break such a paradox. In this study, we theoretically examined the possibility that the human-specific cooperative society can initiate the evolution of innovative behaviors.

Methods

We computationally simulate a co-evolutionary model of cooperation and learning strategies. The schematic representation of the model is shown in Fig. 1. In this model, we assumed two genetically determined behavioral traits: "individualism/collectivism" and "individual learning (IL)/social learning (SL)". Each generation experiences a lifecycle including (1) birth, (2) mutations, (3) innovations by IL individuals, (4) horizontal learning by SL individuals, (5) obtaining resources, and (6) sharing resources by collectivists. Initially, all individuals have individualism and IL alleles, and the simulation runs 10,000 generations. Key parameters in this simulation are the benefit (cost) of collectivism (sharing resources), α , and the number of groups, L, that reflects the number of individuals in each group. We observed the number of individuals that genetically adapt each strategy. Then, the speed of cultural evolution was compared between various conditions. To confirm the results of the simulation, mathematical analyses were also performed.

Results

When collectivism is not beneficial ($\alpha \leq 0$), collectivists cannot survive in the population (Figs. 2a and b). In addition, SL individuals almost occupy the population under this condition. This indicates that IL individuals are weaker than SL individuals under the competition between individuals in our simulation. As collectivism becomes beneficial ($\alpha > 0$), however, the number of IL individuals increases (Figs. 2c and d), suggesting that collectivism rescues the survival of IL individuals. The number of groups, which reflects the number of individuals belonging to each group, also affects the survival of IL individuals (Figs. 2e and f). The number of rescued IL individuals increases with increasing the number of individuals in each sharing group. The speed of cultural evolution depends on the number of IL individuals in the population (Fig. 3).

Discussion

Using computer simulations, the present study suggested that a resource-sharing society rescues risk-taking

innovators. In addition, the simulations demonstrated that, as the number of individuals in each sharing group becomes large, the proportion of innovators and the rate of cultural evolution in the total population increase. This phenomenon is possibly explained as follows: (1) a sharing group having a comparatively large proportion of IL individuals earns a relatively small total amount of resources in the group, (2) a small number of individuals in each group results in a large variance in the number of IL individuals among groups, and therefore (3) the negative pressure on IL individuals becomes stronger as the size of sharing groups is smaller. These results were also showed by a mathematical analysis under some simplifying assumptions. Our findings indicate the possibility that formation of cooperative societies, rescuing risk-taking innovators, is associated with the evolution of the human learning strategy and ability. Along with learning ability, cooperation is also an important behaviour for the understanding of human evolution. Our present study is intriguing in the point of connecting these two human-specific behaviors. It has been suggested that the Neanderthals had small-scale cooperative societies. Therefore, the size of sharing groups may be one of the factors that sealed the fates of two species, Neanderthals and Homo sapiens. The "cooperative society-initiated" hypothesis suggests that most of the members in the society are social learners and only a small number of innovators sustain the cultural evolution. Future studies will address how learning strategy and ability-related genes evolve in such a condition.

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Fig. 1 Simulation model. (a) Hereditary system. A haploid organism with sexual reproduction is assumed. Genes for learning strategies (IL/SL) and cooperation strategies (individualism/collectivism) inherit independently from either of parents. The offspring takes over the technology level (q) from a parent (vertical transmission). (b) Mutations. Genes can reciprocally mutate at a certain rate ($\mu = 0.001$). (c) Innovations. IL individuals make an innovation. The technological advance (s) of the innovation is stochastically given depending on a function f(s; β) = exp(-s/ β)/ β – β . (d) Horizontal transmission. SL individuals observe k individuals obtain resources in proportion to their technology. Collectivists share the resources within the group that depart and gather in every generation. Sharing resources yield a benefit (α >0) or cost (α <0).



Fig. 2 The number of each strategy in the population. The results of 10 simulations were superposed (one in orange and the rest in gray). Ind, individualist; Col, collectivist; α , benefit of collectivism; L, the number of groups.



Generation Fig. 3 Cultural evolution. α, benefit of collectivism; L, the number of groups.

Genome-wide association analysis of cephalic form in modern Japanese

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Introduction

Human head size is correlated with the brain size especially during infancy. Wickett et al. (2000) reported a significant correlation between head perimeter and total brain volume obtained by MRI among healthy adults (r=0.659, P<0.001). Head circumferences is often used as a proxy index for normal brain development in infants, especially in terms of early detection of autism spectrum disorder (ASD) (Kanner 1968; Raznahan et al. 2013). The cephalic index (CI), a ratio of the maximum width to the maximum length of a head multiplied by 100, was traditionally used for clustering human populations in different regions although a few studies have revealed the significance of the environmental factors on CI (Kouchi 2004).

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Genetic basis of normal variation in human head form has remained unclear for a long time except for several genes that are responsible for pathologically abnormal head size, such as *MCPH1* for microcephaly. MCPH1 has played an important role in the evolution of *Homo sapiens* after the divergence from Neanderthals (Green et al. 2010). Recent genome-wide association studies (GWASs) have begun to find genomic regions associated with head size such as infant head circumference (Taal et al. 2012) or adult intracranial volume (Ikram et al. 2012). However, these studies are based on European descendents and may not represent Modern Humans as a whole. In this study, we collected cephalic form data in Japanese and conducted a GWAS to identify the genes accounting for head form, to reveal the genetic basis of head form among Modern Humans.

Materials and methods

We collected DNA sample as well as the size measurements of head for a total of 767 Japanese people residing in Okinawa Island, Okinawa, Japan. Genomic DNA was extracted from blood or saliva of participants and genotyped for 729,172 SNPs using HumanOmniExpress BeadChip system (Illumina, San Diego, CA, USA), and quality control was carried out. The head measurements included the head circumference measured with a tape measure, the maximum head length and breadth measured with an anthropometer, and the cephalic index calculated from the crude measurements. With these head measurements and an index as dependent variables, GWA analyses were conducted using a whole genome association analysis toolset, PLINK, controlling for effect of sex, height, BMI, and principal components of genotype data. The genes that showed significant associations with head size and form were then further examined in terms of comparison with Neanderthal and Denisovan genomes.

Results and discussion

A single nucleotide polymorphism (SNP), rs10470149 located within *LOC284825* on chromosome 21q21.3 was associated with head circumference at a conventional genome-wide significance level ($P<5\times10^{-8}$)(Fig. 1). The derived allele of this SNP was associated with a smaller head circumference. Among the SNPs that had *P*-values

below a threshold for suggestive association (P<1.0x10⁻⁵), rs10236933 fell in *CNTNAP2*, a gene whose relation to ASD and schizophrenia has been reported (Rodenas-Cuadrado et al. 2014) (Table 1, Fig. 1).

Our analysis did not find significant association between head circumference and the SNPs that were associated with infant head circumference (Taal et al. 2012) or adult intracranial size (Ikram et al. 2012) in previous GWASs. In these studies, however, the participants are European descendants. Our results suggest different genetic backgrounds of head size may exist for Asians and Europeans.

As for cephalic index, no SNP showed a significant association at a conventional genome-wide significant level. This is consistent with the findings that a ratio of head breadth to length is affected by environment whereas a sum of breadth and length may be genetically determined (Martínez-Abadías et al. 2009). However, further study with large sample size is needed to confirm the result of present study.

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Fig. 1 A Manhattan plot of a genomewide association analysis for head circumference. Each dot represents a P-value of a SNP for an association after controlling for sex, height, BMI, and population structure (principal components 1 and 2 of genomic variance).

Table 1 A list of SNPs that had P-values below the suggestive level (1.0x10-5) for associations with head circumference. Linear regression analyses were conducted controlling for sex, height, BMI, and population structure (principal components 1 and 2 of genomic variance).

CHR	BP	SNP	Gene	Derived	DAF	Beta	Р	P(GC)	BONF
21	29468403	rs10470149	LOC284825	С	0.1812	-0.4511	2.08E-08	2.11E-08	0.04353
18	62085800	rs2959456	LOC284294	G	0.5945	-0.3238	4.67E-07	4.73E-07	0.9777
16	16052973	rs215101	ABCC1	G^*	0.3129	-0.3368	9.70E-07	9.81E-07	1
18	62087512	rs2909659	LOC284294	А	0.5932	-0.3113	1.26E-06	1.27E-06	1
16	16053729	rs4148333	ABCC1	Т	0.6812	0.321	2.98E-06	3.01E-06	1
7	146337383	rs10236933	CNTNAP2	С	0.2888	-0.3247	3.07E-06	3.10E-06	1
1	111908713	rs1361049	(PIF, PGCP1)	С	0.2529	-0.3214	7.70E-06	7.78E-06	1
7	146356208	rs2533089	CNTNAP2	G	0.3005	-0.3094	7.87E-06	7.94E-06	1
8	20102006	rs2173115	(LZTS1, ATP6V1B2	2) G	0.5391	-0.2814	8.27E-06	8.35E-06	1
6	75342884	rs2485067	RP11-554D15.1 (LOC101928516)	Т	0.1102	-0.4457	8.63E-06	8.71E-06	1
16	16054694	rs215099	ABCC1	А	0.3136	-0.3068	9.13E-06	9.22E-06	1

CHR: Chromosome, BP: Base pair position on a chromosome based on GRCH37/hg19, SNP: Reference SNP ID number, DAF: Derived allele frequency, Beta: Regression coefficient of the derived allele for the association with head circumference after controlling for sex, height, BMI and genomic PC1and PC2, P: crude P-value for the association without genomic control, P(GC): P-value after genomic control, BONF: *P*-value after Bonferroni correction for the number of SNPs.

*: Minor allele instead of derived allele.

The effect of trauma on cultural transmission of Neanderthals

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In many cases, learning how to use our body is necessary to master difficult cultural skills. More advanced cultural skills tend to be more complex and demand longer training of body use. We have to memorize cultural skills not only in our brain but also in our body. Therefore, when an individual suffers a serious traumatic injury on a body part associated with a cultural skill, thereafter he/she may not hold the skill because of the deteriorated physical ability. Since the medical technology of archaic human society was very poor, traumatic injuries may have strongly affected physical ability of individuals, which may have restricted the advancement of the culture.

An analysis of traumatic lesions among Neanderthals revealed that they frequently suffered traumatic injuries on upper body (Berger and Trinkaus 1995). Since upper body is the most important part for humans to hold cultural skills, we can suppose that high injury rate inhibited the maintenance of difficult cultural skills in Neanderthal society. However, how their injury affected their culture has not well investigated, although what kind of culture caused their injuries had been discussed (Berger and Trinkaus 1995; Trinkaus 2012).

To maintain an advanced cultural skill (which can be acquired only by social learning) in the population, an "expert" of the skill must successfully transmit the skill to more than one "novice" of the skill before he/she dies or injures to lose the skill. In other words, before one expert disappears, more than one expert must emerge in the population. When injury rate is high, the skill is less likely to be maintained in the population because two possibilities increase; a possibility that an expert injures and lose the skill before he/she transmits it to novices, and a possibility that a novice already injured and lose the ability for mastering the skill before he/she has a communication with an expert. Therefore, when we take the effect of injury into consideration, each individual must transmit his/her cultural skill to more than one individuals during his/her lifetime. The necessary number of transmittable individuals for the maintenance of a cultural skill in the population depends on the injury rate associated with the cultural skill. In this study we consider the transmission of a series of cultural skills associated with small animal hunting by complex projectile weapons, which may have been absent in Neanderthal society and appeared after the emergence of Modern Humans (Shea and Sisk 2010).

To obtain the necessary number of transmittable individuals corresponding to the injury rate of Neanderthals, in this study, we consider the following cultural transmission model, which is described in Fig. 1. This model is an arrangement of the SIR model that is often used in mathematical biology to describe a transmission of communicable disease through individuals. We consider cultural transmission of a complex cultural skill which can be acquired only by adults. In the adult population, there are three kinds of individuals, novices (N) who have neither the cultural skill nor serious trauma, experts (E) who have the skill without trauma, and traumatized individuals (T) who suffered serious traumatic injury and lose the ability for holding the skill. When a novice closely communicates with an expert, he/she sometimes acquires the advanced skill and becomes an expert. The rate of cultural transmission is β . Both novices and experts sometimes suffers a serious traumatic injury and lose the ability for holding the advanced skill. Traumatized individuals never revert to be novices and experts. The injury rate is γ . Every individual has a same death rate, μ , regardless of the kind of the individual, but new adults emerge in the population with the same rate, μ , so that population size is always constant. There is a possibility that an individual injures before adulthood. The proportion of non-injured individuals in new adults is b. Writing **P11**

the changes of frequencies of three kinds of individuals by differential equations, we have

$$\frac{dN}{dt} = -\beta N E + \mu (h - N) - \gamma N \tag{1a}$$

$$\frac{dE}{dt} = \beta N E - \gamma E - \mu E \tag{1b}$$

$$\frac{dT}{dt} = \gamma(N+E) + \mu(1-h-T)$$
(1c)

Here, N, E, and T are the proportions of novices, experts, and traumatized individuals in the adult population, respectively, so that always holds.

We include Neanderthal fossil data in the above model to estimate parameters of Neanderthals. From Trinkaus (2011) and Caspari and Lee (2006), the annual death rate of adult Neanderthals, μ , isestimated around 0.07-0.085. From Berger and Trinkaus (1995), Wu et al. (2011), and the Catalogue of Fossil Hominids Database, the proportion of traumatized individuals who lost the capacity for cultural skills associated with small animal hunting by complex projectile weapon, \hat{T} , is estimated around 0.5-0.6. From Trinkaus et al. (1994), Berger and Trinkaus (1995) and Trinkaus (2011), the proportion of non-injured individuals in new adults, h, is estimated around 0.8-0.85. Including these values into the mathematical model, we can estimate the annual injury rate of adult Neanderthals, γ , the critical cultural transmission rate of Neanderthals, β^* , and the critical number of communicable individuals during adulthood in Neanderthals, β^* / μ , shown in Table 1.

Note that to obtain the critical number above, we assume that the cultural skill is always transmitted from an expert to a novice when they closely communicate with each other. However, in reality, cultural traits are not necessarily transmitted between them even when they have a close communication, because some experts learn wrongly, do not have a motivation to learn, or some experts do not demonstrate the skill. Therefore, communicating far more than 4-6 individuals, probably 10-15 individuals, during adulthood may have been actually necessary for maintaining the cultural skills in Neanderthal society.

Ancient genome sequences suggest that Neanderthals may have commonly mated among close relatives probably because of small community size (Prüfer et al. 2014; Castellano et al. 2014). Therefore, it may have been almost impossible for Neanderthals to communicate closely with more than 10-15 individuals during adulthood. Thus, we can conclude that it was difficult for Neanderthals to maintain advanced cultural skills that demand a mastery of difficult physical techniques, because their injury rate was too high and their community size was too small.

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The Catalogue of Fossil Hominids Database. http://fossil.kochi-tech.ac.jp/



Fig. 1 The description of the NET model.

μ	\hat{T}	h	7	β	β^*/μ
0.078	0.55	0.83	0.066	0.32	4.1
0.070	0.55	0.83	0.059	0.29	4.1
0.085	0.55	0.83	0.072	0.35	4.1
0.078	0.50	0.83	0.051	0.26	3.3
0.078	0.60	0.83	0.084	0.40	5.2
0.085	0.55	0.80	0.061	0.31	4.0
0.085	0.55	0.85	0.069	0.33	4.2

Table 1 Estimated values of parameters.

A population-genetics based model for explaining apparent cultural continuity from the Middle to Upper Palaeolithic in Eurasia

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Aim

In this study, we construct a mathematical model to simulate the invasion of *Homo sapiens* (HS) into a region preoccupied by an archaic hominin (AH) species and associated acculturation on the side of HS. The purpose is to identify the major determinants of the pattern of cultural shifts associated with biological replacement. We analyze the model using analytical approximation techniques and individual-based simulations. Based on the results, we discuss the possible causes of a variation between different regions in the pattern of cultural shifts during the MP-UP transition.

Model

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Our model is simplistic in many respects to extract essence and also to maintain analytical tractability. Imagine that a small population of HS is invading into a region preoccupied by an AH species. Suppose that this region accommodates a total of exactly N individuals of the AH or HS, where N is constant. Suppose, again for simplicity, that those populations reproduce asexually, so that each individual has only one parent. Generations are discrete in so far as cultural transmission occurs. HS is initially rare in frequency, given that they have just arrived at this region. Let p denote the frequency of HS in the focal region and p_0 the initial frequency. The AH is less viable than HS for some unspecified reason and therefore the latter increases in frequency and eventually replaces the former. We assume that the relative fitnesses of HS and the AH are 1 and 1-s, respectively. Since the population size is finite, HS may undergo local extinction with a positive probability due to random sampling drift despite selective superiority. However, we set Ns sufficiently large, so that the probability of extinction for HS is negligible.

We assume that cultural transmission may occur from the AH to HS, while we neglect that in the opposite direction for simplicity. We assume that the AH and HS initially have different phenotypes with respect to a cultural element, referred to as C_A and C_H , respectively. We assume that each individual of HS learns vertically and obliquely with probabilities $1-\gamma$ and γ , respectively. When an individual of HS learns obliquely, he/she may copy either a conspecific or an individual of the AH in the parental generation. As a result, the cultural trait C_A can gradually spread into the population of HS. We assume that the probability that an individual of HS copies an individual of the AH, denoted by $X(u, \rho)$, is given by

X(u,p) = (u(1-p))/((1-u)p + u(1-p)),(1)

where *u* represents the tendency to learn from the AH and may range from 0 to 1; *u*=0 represents an extreme situation where HS never copies the AH. On the other hand, *u*=1 implies that individuals of HS, when they learn obliquely, always choose to copy the AH. When *u*=1/2, HS has no preference with respect to the role models for oblique social learning. It must be noted that the probability of learning C_A may be higher than equation (1) because individuals of HS may also bear C_A . We assume that transmission of a cultural character is always faithful

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and perfect, so that social learning never fails.

We assume that the two phenotypes C_A and C_H are selectively neutral. We investigate how the pattern of cultural dynamics depends on selection coefficient *s*, initial frequency p_0 , oblique transmission rate γ , and tendency to learn from the AH *u*. We are particularly interested in the probability that C_A persists despite biological replacement and also the time until it is lost after the replacement.

Results

We can loosely categorize the patterns of cultural dynamics based on some results of individual-based simulations.

Pattern A (Immediate loss of C_A): C_A is quickly lost during biological replacement. This pattern occurs when selection is strong (*s* is large), the initial frequency of HS is high (p_0 is large), the preference for the heterospecific culture is low (*u* is small), and/or the oblique transmission rate is low (γ is small).

Pattern B (C_A keeps to be frequent): C_A continues to be very frequent during biological replacement and persists forever. This pattern occurs when selection is weak (*s* is small), the initial frequency of HS is low (p_0 is small), the preference for the heterospecific culture is high (*u* is large), and/or the oblique transmission rate is high (γ is large).

Pattern C (Gradual loss of C_A): C_A decreases in frequency during biological replacement. It persists for a long time after the replacement but eventually goes extinct. This pattern occurs under conditions intermediate between the patterns A and B.

Pattern D (Temporal decrease in the frequency of C_A): C_A reduces its frequency during biological replacement. However, it increases in frequency again, eventually reaches fixation, and persists forever. This pattern also occurs under conditions intermediate between A and B.

Testing the hypothesis on cognitive evolution of Modern Humans' learning ability: Achievements of past-climatic approaches

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The impact of climate change on human evolution is important and debating topic for many years. Since 2010, we have conducted a general joint project entitled "Replacement of Neanderthal by Modern Humans: Testing Evolutional Models of Learning", which based on a theoretical prediction that the cognitive ability related to individual and social learning divide fates of ancient humans in the very unstable Late Pleistocene climate. This model predicts that the human populations which experienced a series of environmental changes would have higher rate of individual learners, while detailed reconstructions of global climate change have reported fluent and drastic change based on ice cores and stalagmites. However, we want to understand the difference between anatomically Modern Human which survived and the other archaic extinct humans including the European Neanderthals and Asian Denisovans.

For this purpose the global synchronic change is not useful for understanding but the regional difference in the amplitude and impact on biome of climate change is the information required. Hence, we invited a geophysicist using Global Climate Model (GCM) to reconstruct the climatic distribution and temporal change in a continental scale. At the same time, some geochemist and geographers construct a database of local climate changes recorded in different proxies. At last, archaeologists and anthropologists tried to interpret the emergence and disappearance of human species in Europe and Asia on the reconstructed past climate maps using some tools, such as Eco-cultural niche model. Our project will show the regional difference in climate change and related archaeological events and its impact on the evolution of learning ability of Modern Humans.

Stadial and interstadial climates in the Late Pleistocene, as simulated in experiments with the MIROC climate model

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The Late Pleistocene was a period which lasted from the Eemian interglacial period, approximately 126,000 years ago, to the start of the warm Holocene, 11,700 years ago, and was characterized mostly by widespread glacial ice. Ice core data reveal abrupt climate changes, known as the Dansgaard-Oeschger events during which relatively rapid warming in excess of 8°C occurs over Greenland within the span of a few decades, followed by progressive cooling over 1,000 years or more. Some of the cool stadial states coincide with Heinrich events when icebergs broke off from the melting Laurentide ice sheet and ice rafted debris carried by the traversing icebergs were deposited on the sea floors of the North Atlantic Ocean. The Late Pleistocene was also a period which saw Modern Humans spread throughout the world and other species of the same genus such as the Neanderthals become extinct. Various hypotheses have been put forward to explain the extinction of Neanderthals, the last remains of which date back to about 30,000 years ago (Finlayson et al, 2006). Among these is one which involves abrupt changes in past climate and the inability of Neanderthals to adapt to such changes (Finlayson and Carrión 2006; Müller et al. 2011). The large discharge of freshwater into the North Atlantic Ocean during Heinrich events is thought to have greatly weakened the Atlantic meridional overturning circulation, lowering North Atlantic sea surface temperatures (SST) with major environmental consequences across parts of Europe such as cooling, aridification and a reduction in forest cover.

In order to assess the effects of abrupt climate change on past human migration and on the extinction of certain species, it is first important to have a good understanding of the past climate itself. Previous investigations on abrupt climate changes during the last glacial period have used climate models forced under reduced North Atlantic SST (e.g. Barron and Pollard 2002; Sepulchre et al. 2007). Some of these have also looked into the vegetation response to these climate changes, either by using these reconstructed climate from atmosphere models or by using those from an atmosphere-ocean coupled model in which a freshwater flux is applied over the North Atlantic to simulate the reduction in SST there (Woillez et al. 2013).

In this study, we use three variants of 'The Model for Interdisciplinary Research on Climate', or known simply as MIROC (K-1 Model Developers 2001), a global climate model, for a time slice experiment within the Late Pleistocene: two mid-resolution models (an atmosphere model and a coupled atmosphere-ocean model) and a high-resolution atmosphere model. To obtain a fuller picture, we also look at a cool stadial state as obtained from a 'freshwater hosing' coupled-model experiment, designed to mimic the effects of freshwater discharge in the North Atlantic, as applied to a mid-glacial climate state. We use the sea surface temperature response from this experiment to drive the atmosphere models. The surface air temperatures exhibit an antisymmetric pattern whereby cooling is seen across most of the northern hemisphere and weak warming is seen in parts of the southern hemisphere (Fig. 1). This is accompanied by drier climates in the north and wetter climates in the south, in particular over the Southern Atlantic Ocean and northeast South America, indicative of a southward shift of the Intertropical Convergence Zone. More detailed features of the model-simulated climates are discussed and the results are compared with some available proxy data to elucidate where model simulations show good agreement. The output from these climate model experiments are used to drive the Lund-Potsdam-Jena dynamic global vegetation model (Sitch et al. 2003) so that we can investigate changes in vegetation when the climate enters the cold stadial phase. In general, there is a reduction in forest over most of Europe, especially over the British Isles, north of central Europe and north of the Caucasus (Fig. 2). Much of this is replaced by grassland. On the other hand, there is also a small area stretching from the eastern coast of the Iberian Peninsula, across the islands in the western Mediterranean, to the western coast of Italy where forest cover increases.

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Fig. 1 The annual mean change in surface air temperature and precipitation when freshwater hosing conditions are applied to an atmospheric model.



Fig. 2 Forest, grass and bare ground fractional changes across Europe, as calculated by a dynamical vegetation model. Positive values correspond to increases when freshwater hosing conditions are applied.

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Geochemistry of Neanderthal and Modern Human archeological sites: Evidences of paleoclimatic variations and *Homo s.* activities

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Introduction

On current evidence, southern Iberia is the region where the extinction of the last Neanderthal populations took place (Finlayson et al. 2006). This information has been obtained from different archeological places located in cave and rock shelters like those where is based our study: Gorham's, Bajondillo, El Pirulejo and Vanguard. These kind of depositional environments contain major information about past *Homo* activities, paleoenviromental sequences and faunal/floral evolution. Nevertheless, cave deposits are formed by a combination of erosional, structural, karstic, biological and diagenetic process making these systems very complex from a geological point of view: each cave presents its own unique features. Inorganic geochemistry can help us to resolve this complexity by distinguishing the composition and evolution for the three major inputs that compose cave deposits: inorganic, organic and diagenetic.

Inorganic input to caves is associated with autochthonous minerals originating through calcite dissolution (the so-called "terra rossa"), and external inputs. External inputs are mainly related to: (a) aeolian input in southern Iberian coastal outcrops (Gorham's, Vanguard and Bajondillo); and (b) surface or near-surface materials occurring around the cave, usually after suffering a certain degree of pedogenesis, in those more continental (El Pirulejo). Organic deposits are associated with faunal/floral remains, guano, artifacts and combustions remains (hearths), among others. Diagenesis promotes new minerals formation (calcite, silica, etc) and also can affect element distribution along soil profile, among other phenomena. These inputs during the conditions of formation can be characteristic and can generate a distinctive geochemical imprint.

This study aims to discover formation process, local disturbance, lateral progressive variations (e.g., entrance to deep location and hearth distances), diagenetic effect, identify new proxies for anthropogenic activities and evaluate contamination levels associated to these activities.

At the continental site of El Pirulejo an Upper Paleolithic sequence has been described, including Solutrean and Magdalenian (from 18 to 10 kyr) and Bronze Age activities. Preliminary results at El Pirulejo indicate that Bronze Age archeological levels show high contents in Pb and Cu. These elements are almost absent in Paleolithic levels and this presence between those is a clear indication of post-depositional alteration of these older levels associated to burials digging during the Bronze Age.

At coastal sites we can reconstruct the presence of Saharan aeolian input by the La/Lu ratio. The La/Lu ratio has been specifically used to discriminate aeolian inputs of the African craton from those of the European margin (Cortés-Sánchez et al. 2012). The highest La/Lu values develop during Heinrich events that represent cold and arid episodes in this region which are associated with occupational hiatuses, affecting both, Neanderthals and Modern Human populations (Jimenez-Espejo et al. 2013). In these locations detrital proxies (K/Al and Mg/Al)

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show homogeneous values along similar stratigraphic levels, indicative of lower bio-turbation in the deep part of the cave, where a sub-horizontal stratigraphy has been preserved (Finlayson et al. 2006).

Samples obtained from clearly defined hearths have been compared with experimental fires allowing recognition of a batch of elements associated to ash input. Very high values have been reached at specific points, allowing us to indicate the earliest presence of anthropogenic mediated contamination in the geological record associated to Neanderthals (Gorham's Cave) although they can also be associated with diagenetic accumulations. In addition, available data indicate certain similarity in rare earth element composition between ash elements and those associated to guano and discrimination between these sources requires further work. In any case it is remarkable that the ash/carbon related element exhibits a homogeneous dispersion along levels associated with hearths (Vanguard Cave), pointing to ash redistribution along the cave by Neanderthals, as observed in other locations (Vallverdú et al. 2010).

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Endocast surface reconstruction from CT images

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Introduction

An endocast is the internal cast of a cranium where a brain shape is stored. Extracting geometric models of endocasts is an important issue in anthropology, because endocasts give us various useful anthropological information such as brain shapes and their volumes. We usually use CT scanners, non-destructive measurement devices in order to extract geometric data of crania. The scanned result or CT images contain scalar value (CT value) corresponding to the materials. Since CT value is proportional to material density, the surfaces can be extracted by common isosurface extraction methods (Lorensen 1987) with an isovalue. However, this approach is difficult to extract endocast surfaces, because the isosurfaces contains whole surface of crania and an additional manual operation is required for extracting only endocast surfaces.

We introduce a computational method for extracting endocast shapes from CT images of crania. From our observation, we found the endocast is the largest empty space in a cranium. We use this heuristics for automatic endocast surface extraction problem. Our method is based on the watershed-based segmentation (Vincent 1991) using distance fields. We first compute distance fields from a binary images of a cranium. Next, we find initial seed voxels using the distance field so that a part of endocast region and corner voxels are individually selected. Finally, the watershed segmentation is applied to the binary images and they are classified into crania part, endocast part and background part. We use this segmentation result for polygonization of the endocast. We also demonstrate our method can extract polygonal meshes from CT images of various kinds of crania including, monkey and assembled fossil crania.

Algorithm

Our endocast extraction method consists of four steps (Fig. 1) and their details are described below.

The first step is the determination of crania objects from CT images. This consists of two steps; binarization and noise removal. Binarization classifies the input images into a crania shape and background and we binarize this with an isovalue *t*. The results often contain noise due to scanning artifacts and we apply labelling to find connected components to the results and the largest component is extracted as foreground voxels or the cranium object.

The next step is to extract an endocast voxels from the binary images by using watershed algorithm using distance fields (Fig. 2). We first compute distance field (Lohmann 1998) from the binary image (Fig. 2 (b)). Next, we find initial seed box v such that $d(v) > k \max d(v)$ where d(v) and k denote the distance value at v and user-given parameter respectively. We choose k so that a few endocast voxels and background voxels are selected. In addition, we also select corner voxels of the binary images as initial seed voxels because boundary voxels must become single component. We apply the labeling to the initial seed voxels and the two components are labelled (Fig. 2(c)). Then, the watershed algorithm is applied to expand initial seeds using distance value. When the algorithm is

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terminated, the input volume data is decomposed into cranium part (white), endocast part (red) and background part (yellow) shown in Fig. 2(d).

The final step is polygonization of endocast region classified in the previous step. We here apply Marching cubes to masked cells so that any unmasked cells are not polygonized. The isovalue is same as that used in the first binarization step.

Results and discussion

Experimental results are shown in Fig. 3. In each example, an isosurface of CT images and the result are drawn in gray and red respectively. We confirmed that the endocast surfaces could be extracted from various types of examples, including a monkey (Fig. 3 (b)) and a fossil cranium (Fig. 3 (c)). Note that sub-voxel accuracy is guaranteed since polygonization is based on Marching cubes.

The statistics of the experiments are summarized in Table 1. All the experiments are tested on Windows PC (Intel Core i7-3930K CPU + 64 GB RAM). Each computation is automatic and computation time is about ten minutes. Our method has two major parameters: isovalue t and scaling factor k. In particular, we have to select s carefully so that initial seed voxels are decomposed into two components. For instance, base of the skull is often lost in fossil cranium models and the holes are relatively large. In such cases, we need to select larger scaling parameter. This parameter tuning is easy by using rendering results.

Our method has two limitations. The first limitation is that surface quality depends on the quality of binarization. Since the current implementation uses a single threshold, thin features are often lost by binarization. The second limitation is that our method is difficult to control surface boundary. Our method is designed for extracting the inner surface of a cranium and unnecessary region is extracted from incomplete models such as fossil crania (Fig. 3(c)), additional removing operation may be required to extract endocast surfaces. However, the task becomes much simpler than conventional approaches.

Conclusion

We have introduced a method for computing endocast polygons from CT images of crania. Our method extracts the endocast region by watershed algorithm. Polygonization of endocast surfaces is computed by Marching cubes algorithm with the segmentation result as mask images. Experimental results showed that our method can extract endocast polygons from various kinds of crania with few parameter settings. As a result, the task of extracting endocast becomes much simpler.

There are some future issues for this research. Main issue is to introduce non-uniform polygonization from volume data. Particularly, per-voxel threshold is required for high-quality binarization. The other issue is to find initial seed automatically.

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Fig. 1 An overview of our method. (a) Input volume data (512x512x301 voxels). (b) Binarization result. (c) Segmentation result (red). (d) Endocast polygon of (a) (803,296 faces).



Fig. 2 Endocast segmentation based on watershed algorithm. (a) Binary image. (b) Distance field. (c) Initial seed voxels (red/ yellow) computed from distance value. (d) Segmentation result.



Fig. 3 Results.

Data	Parameters				
Name	Size	t	k	#faces	Time [s]
KUMA (Fig. 1)	512x512x301	25	0.35	803,296	304.5
K2589 (Fig. 3 (a))	512x512x399	45	0.85	1,052,296	443.7
M15 (Fig. 3 (b))	512x512x253	230	0.15	182,280	585.7
Mladec1 (Fig. 3 (c))	512x512x360	910	0.35	1,137,492	377.7

Reconstruction of Qafzeh 9 braincase and its endocast morphology

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Introduction

Paleoneurology is an important field in the study of human evolution as it contributes important information to other areas of paleoanthropology. Variations in the size and shape of endocasts help in differentiating among fossil species. Moreover, comparisons of the size and shape of the fossil endocasts provide considerable links of the hard evidence to behavioral and cognitive differences among fossil species, which might have drove the speciation between the taxa. In this context, C01 team of the project RNMH (Replacement of Neanderthals by Modern Humans) aims to present reasonable ways for reconstruction of the fossil hominids in order to estimate the endocasts and the brains, and also aims to make possible inferences for behavioral and cognitive differences between Neanderthals and Modern Humans, based on the estimated endocasts and brains.

Preliminary results and the scope

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In this paper, we describe the endocast of Qafzeh 9 and compare the size and shape of it with those of Modern Humans and several fossil hominids. The endocast reconstruction of the Qafzeh 9 has been accomplished by ourselves (Kondo et al. 2014), where a semi-virtual reconstruction was performed by using sequential CT images of the present cranial reconstruction with their planar resolution of 0.41 mm/pixel and the slice thickness of 0.5 mm. The process followed that of Kubo and Kono (2011), i.e. after extracting the cranial model from the CT images by using a threshold between the bone and air and making a physical mold of the endocranium with 3D printer, we filled the gap and repaired the lacking portions of the inner cranial surface with clay. The more complete surface model of the endocast was produced from re-scanning images of the repaired mold. At the same time, with assessment of the degree of R-L asymmetry of the original fossil cranium, we have tried to correct the observed degree of deformation or distortion along the most variant direction against the normal R-L asymmetry of Modern Human crania. The assessment suggested that the present reconstruction of the Qafzeh 9 cranium, possessing a significant degree of R-L asymmetry, might have suffered from distortion (Kondo et al. 2014).

Directly measured endocranial volumes, 1411 cc for the original reconstruction and 1477 cc for the morphed version, respectively (Fig. 1) were smaller than previously published data (1531 cc, Holloway et al. 2004) using least-square regression equations. After morphing, the endocast was higher at the middle cranial fossa and narrower at the frontal lobe, both characteristics falling within the range of recent human variation. Although the reconstructed Qafzeh 9 endocasts of both the original and morphed versions fit into the endocranial evolution among lineages of the genus Homo, many fossil crania may have undergone a substantial degree of taphonomic deformation. Therefore, application of possible corrections or hypothesis of plausible taphonomic scenarios should be part of a reasonable assessment of a single precious fossil specimen.

Qafzeh 9 was discovered and excavated by B. Vandermeersch in 1969 from the Qafzeh Cave in Israel. It was associated with Middle Paleolithic assemblage of the Levalloiso-Mousterian culture (Vandermeersch 1981).

In spite of the older chronological age over 90,000 years and the older type of associated lithic assemblage (Tabun C type in Middle Paleolithic), the human skeletal morphology from the Qafzeh Cave is quite modern and contrasted to those of contemporary or even younger classic Neanderthals. According to his first description, the Qafzeh 9 individual is an adult female, whose cranial bones were crashed and heavily fragmented, but the whole cranium was well restored and reconstructed (Vandermeersch 1981). The endocranial feature was only described on the parietal meningeal vessels because no endocasts have been made for this specimen. Therefore, even now we know the present reconstruction exhibits possible distortions both in the neurocranium and the face, it is worth describing the original version of the endocast and then comparing the size and shape of both the original and the morphing version with those of modern and fossil humans.

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Fig. 1 Reconstruction of Qafzeh 9 endocast. org: original version in the left, mor: morphing version (reduced R-L asymmetry) in the right (modified from Kondo et al. 2014).

Surface deformation of crania by optimizing rigidity

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Introduction

Shape deformation is a useful tool in geometric morphometrics, since it can be used to reconstruct missing parts and transfer semi-landmarks. Thin-plate spline (TPS) warping (Bookstein 1989), which minimizes the bending energy of transformations, is a predominantly used deformation method in geometric morphometrics. Missing parts are reconstructed by transforming a reference model (that has no missing parts) to a model with missing parts (Gunz et al. 2009). The warping function of TPS can be computed by solving dense linear systems of size (k + 4) × (k + 4), where k is the number of interpolation points (i.e. landmarks).

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TPS warping can also be used to transfer semi-landmarks. Suppose we have two models A and B, where only model A has semi-landmarks, and we want to transfer the semi-landmarks from A to B. The sliding semi-landmark method (Bookstein 1997) positions the semi-landmarks on B so that the induced TPS warping has the minimum bending energy. The variables in this minimization problem are the coordinates of the semi-landmarks on B and, since the semi-landmarks are needed to lie on B, this is a constrained minimization problem. Local minima of the problem are computed by alternating between relaxed optimization and projection. In the relaxed optimization step, the constraints that semi-landmarks lie on B are removed and, instead, each semi-landmark s on B is allowed to move on the tangent plane of B at s. With these relaxed constraints, the optimization can now be solved by solving linear systems. In the projection step, semi-landmarks that move away from B in the relaxed optimization step are projected back to their closest points on B.

There are mainly two types of methods for shape deformation: space deformation and surface-based deformation. Space deformation methods deform a surface by deforming a space that encloses the surface; the surface is implicitly deformed according to the deformation of the space. TPS warping is a space deformation method that deforms the entire 3D space. Space deformation methods are robust in the sense that they can operate on imperfect data such as point clouds, triangle soups and surface meshes with bad shape quality. Surface-based deformation methods directly deform a surface. Variational surface-based deformation methods compute the deformation by minimizing some deformation energy (such as bending energy) and they achieve high quality shape-preserving deformation.

Several linear variational methods that minimize linearized deformation were proposed in recent years (Botsch and Sorkine 2008). They are fast, since the deformation is computed by solving (sparse) linear systems. However, they might cause artifacts in the deformed surface. As-rigid-as-possible (ARAP) surface deformation (Sorkine and Alexa 2007) is a popular surface-based deformation method in geometric modeling that avoids the artifacts of linear variational methods. The ARAP surface deformation method computes a high quality shape-preserving deformation by minimizing the ARAP deformation energy. Though its energy formulation is non-linear, it is conceptually simple and easy to implement. In this work, we apply ARAP surface deformation to Modern Human crania and compare the results with the ones obtained by TPS warping.

Method

As-rigid-as-possible (ARAP) surface deformation finds a transformation that is locally a rigid transformation. The ARAP energy formulation is derived as follows (Sorkine and Alexa 2007). Suppose we have a surface mesh S whose vertex set is V and edge set is E. We denote the deformed surface mesh as S'. The ARAP energy measures the local deviations from rigid transformations and is defined as

$$E(S, S') = \sum_{i \in V} w_i \sum_{j \in N_i} w_{ij} \left\| (p'_i - p'_j) - R_i (p_i - p_j) \right\|^2$$

where p_i is the position of the *i*-th vertex of S, p_i' is the position of the *i*-th vertex of S' and N_i is the set of neighbor vertices of vertex p_i . w_i is the weight of vertex pi and w_{ij} is the weight of the edge connecting p_i and p_j . R_i is the optimal local rotation that transforms the neighbors of pi to those of p_i' . In shape deformation, the original surface mesh S is fixed and some vertices under positional constraints in S' are also fixed. Thus, the ARAP energy becomes the function of the coordinates of unconstrained vertices in S'. The ARAP deformation method computes these coordinates by minimizing the ARAP energy. Sorkine and Alexa (2007) solve this minimization problem by a twostep alternating optimization:

• Fix the local rotations R_i ($i \in V$) and optimize the positions of unconstrained vertices in S'.

• Fix the positions of unconstrained vertices in S' and optimize the local rotations R_i ($i \in V$).

This optimization deals with R_i as if they are independent variables from pi and its neighbor vertices. Suppose we have a reference mesh A (that has no missing parts) and a mesh B with missing parts, where both A and B have landmarks. To reconstruct missing parts, we compute a deformed reference mesh A' using ARAP deformation under the following positional constraints: the position of each landmark on A' is set to that of the corresponding landmark on B. By optimizing the positions of unconstrained vertices in A' using the ARAP energy, we obtain a desired deformed mesh A'.

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Neural underpinning of creative thinking: A meta-analysis for neuroimaging data

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Introduction

The target of our research project is to investigate whether the cause of phenomenon for replacement of Neanderthals by Modern Humans can explain according to difference of cognitive mechanism for learning behavior from a viewpoint of neuroscience. For this purpose, we compare morphological differences of brain between Neanderthals and Modern Humans by using computational data of fossil crania. And, difference of neural representation for learning behavior could be discussed based on those morphological differences. To discuss the difference of neural representation, it is necessary to depict a cognitive mechanism in which a difference is predicted among Neanderthals and Modern Humans. And, it is also necessary to discuss the difference of functional representation of that cognitive mechanism on brain region, that is obtained from contemporary human subjects, by projecting virtual Neanderthal brain.

Cognitive mechanism of creative thinking is one of the convincing candidates which represent the difference of Neanderthals and Modern Humans. It is considered that the drastic climate change repeatedly arose in the age of replacement. In order to survive under the environment, creative and adaptive behaviour might be required for various circumstances. Therefore, we expected that difference of cognitive mechanism to demonstrate the creativity might be represented the difference of behaviour required for survival. And, the replacement arose because the Modern Human who possessed capacity for creative and adaptive behaviour to survives in environmental perturbation. Recent reviews of neuroimaging for creativity (Dietrich and Kanso 2010; Arden et al. 2010) suggested that neural underpinning of creative thinking could not be explained depending on the single cognitive process or cortical region. Thus, it is necessary to clarify a common neural underpinning of creativity based on various kinds of experimental task to depict the creative behaviour.

The purpose of the present study is to depict the neural representation of creative behaviour to discuss the difference of cognitive capability between Neanderthals and Modern Humans. For this purpose, we use a metaanalysis method for neuroimaging data to create functional map of creative behaviour. The research articles of functional magnetic resonance imaging (fMRI) study for creative thinking are collected, and common cortical regions representing creative thinking is depicted by using the activation likelihood estimation (ALE) method based on the reported cortical activation.

Method

In the present study, we collected forty research articles describing neural basis of creative thinking measured by fMRI. For details, twenty-six articles for fMRI investigations using verbal creative task, six articles for fMRI investigations of creativity task using figure information, and eight articles for fMRI investigations using artistic creativity were collected.

Based on activation tables which were reported in the collected articles, the three-dimensional coordinate of each activation peak was extracted. Montreal Neurological Institute (MNI) coordinate was used in whole

analysis. As the experimental task which produces creative activity, various kinds of experimental task were used in each fMRI measurement. Therefore, We extracted activation peaks of subtraction analysis between experimental condition with creative thinking and either conditions of lower control condition or resting condition, in order to describe the cortical activity common to various creative activities. The coordinate of activation peak which was reported using Talairach space was converted to MNI space using the MTT transform (Lancaster et al. 2007). Consequently, 473 activation peaks were extracted.

A meta-analysis for activation peaks was performed using GingerALE software (BrainMap.org; http://www. brainmap.org/ale/) which provide common activation maps from dataset using Activation Likelihood Estimation (ALE) method (Eickhoff et al. 2009, 2012; Turkeltaub et al. 2012). In order to estimate the common activation pattern of creative behavior, ALE method was performed considering the extracted activation peals as one dataset. The less conservative mask was used because it was for taking into consideration fluctuation of the activation peak located on the surface region of cerebrum. As a result of masking process, thirteen activation peaks were discarded. The ALE map and the P value on each voxel were calculated, and statistical threshold for ALE map was set by p < 0.01 using False-Discovery Rate (Laird et al. 2005).

Result and discussion

As a result of meta-analysis, cortical regions with statistically significant ALE value were observed in many different cortical regions (Fig. 1). As the significant clusters in the frontal region, eight clusters were observed on left lateral prefrontal region, two clusters were observed on right lateral prefrontal region, and two clusters were observed on left parietal region, four clusters were observed on left temporal region, four clusters were observed on occipital region, and two clusters were observed on right cerebellum.

As an overall trend, the activation clusters were observed by predominance in the left hemisphere. This trend was remarkable also in the prefrontal area. The left prefrontal area is strongly related to linguistic processing. Since many of experimental tasks which were used in collected articles were used creativity test on verbal information, the activation cluster in left prefrontal cortex was reflecting verbal processing. But, it was also observed that cortical activations during artistic creativity tasks were involved in the ALE value of this cluster, the left prefrontal cortex is synthetically important for creative thinking. That result is consistent with the suggestion in previous reviews of creativity (Dietrich and Kanso 2010; Arden et al. 2010).

Significant clusters were also observed in the left parietal and temporal cortex and right cerebellar posterior lobule. In our group's research about a reconstruction of the virtual Neanderthal brain using computational anatomy (Tanabe 2014), it was presumed that these regions had morphological differences between Neander-thals and Modern Humans. That is, the volume of the parietal cortex and cerebellum of virtual Neanderthal brain might be smaller than that of Modern Human, on the other hand the region from a posterior temporal to occipital cortex might be larger in virtual Neanderthal brain. When the morphological and functional differences are taken into consideration together, the difference of creative thinking between Neanderthals and Modern Humans may be inferred from the morphological difference on cognitive network entire brain representing creativity. Thus, the present result provides a possible data to discuss the difference of cognitive mechanism for learning behavior.

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Fig. 1 Significant activation clusters which are commonly observed during creative thinking tasks. Z-value indicates the value of MNI coordinate on the z-axis from the origin towards the top of the head.

fMRI Experiment about executive function by difference of learning methods: Using Tower of Hanoi

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Introduction

In the previous report, we measured and analyzed 3D motion data by subject that has expert skills of the recurrent Levallois method. Execution of stone-tool production was shown to concern with "social learning" and "individual learning" by our results. In this study, our purpose is to verify effect of executive function by social learning or individual learning from fMRI analysis. Executive function is defined as "the ability to retain a relevant stance for the goal of future", and consists of (1) goal formulation, (2) planning, (3) carrying out goal-directed plans and (4) effective performance (Muriel 1982). Then, executive function is lower brain functions that consist division attention, management of tasks, conversion ability to think and inductive guess. Execution of stone-tool production in MRI is impossible, so we select the Tower of Hanoi as the task for executive function analysis in this experiment (Humes et al. 1997). In this paper, we explain the experiment environment and the results of fMRI analysis and task performance data.

Experiment

This experiment was used our designed Tower of Hanoi task in fMRI. Purpose of this experiment is to verify the effect of learning method using fMRI analysis. Subjects were three men in their twenties. In order to analyze the effect of learning methods, three men played either of three groups of "non learning", "individual learning" and "social learning". Non learning group did not have learning period in the experiment. Individual learning group had learning period that is practice of Tower of Hanoi. Social learning group had learning period with teacher. Fig. 1 shows this experiment time schedule of each group.

Subjects performed the Tower of Hanoi task of onscreen using controller in MRI. This task has three to six disk of Tower of Hanoi. This experiment has two sessions (Session:1, Session:2). A session is consisted of eight Task parts (Task1 & Task2 * three to 6 disks), eight Repeat parts (Task1 & Task2 * three to 6 disks) and some rest parts. Fig. 2 shows detail time sequence of a session.

Task and Repeat have two parts of Tower of Hanoi task by three to six disks. In Task parts, Subjects performed a repeat in part time (40 second). In Repeat parts, the screen was displayed his moved disk of Task part (40 second). Therefore, subjects looked the screen, and performed same control. In rest parts, subjects did not perform or think (15 second). In this fMRI experiment, we measurement the average performance time and task completed count. In the next heading, we report some results about fMRI analysis, performance measurement.

Results

Average performance times of all subjects are shown in Fig. 3.

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About tendency of non learning subject results, average performance times are almost constant in all tasks. Individual learning subject and social learning subject results of average performance time were shown each tendency. About tendency of individual learning subject, average performance times of Session:2 were shorter than Session:1. In particular, tasks of six disks have notable difference. Average performance times of social learning subject also were short at Session:2. However, times of Session:2 six disks were longer than Session:1. We think that this reason is delay by recalled of learned subject. From these results, we think that non learning subject did not learn about task in experiment, but it is evident because he did not have learning period. Performance of individual learning subject and social learning subject improve after the each learning, so we think that individual learning subject and social learning subject progress learning.

Next, fMRI analysis data of individual learning subject and social learning subject are shown in Fig. 4.

Results of Fig. 4 are difference of Session:1 and Session:2 at six disks. Learning progresses of individual learning subject and social learning subject were observed from results of performance measurement, but differences by effect of learning are not observed from fMRI data results. We think that this cause has some problem to task design. One problem is that we need observe until end of learning. Then, we need conduct experiment with more subjects. Other detail results will report at this conference.

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Fig. 1 Experiment time schedule of each group.





Fig. 3 Average performance times of each task.

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Fig. 4 fMRI analysis data of individual learning subject (a), social learning subject (b).

Brain structural and functional analyses for motivation to learn, fatigue and cognitive function

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Differences in learning abilities between ancient and modern humans can be demonstrated by using functional and structural neuroimaging methods to identify the brain regions that are involved in learning in modern humans, and then by using fossil reconstruction to compare these regions between modern and ancient humans. The research term C02 (Functional Mapping of Learning Activities in Archaic and Modern Human Brains), part of the study project for Replacement of Neanderthals by Modern Humans (RNMH), has focused on factors for enforced learning such as creativity and social cognition.

The motivation to learn is one such factor. We have used functional magnetic resonance imaging (fMRI) in order to investigate the neural substrates of the motivation to learn in modern humans. We confirmed that sense of accomplishment was an intrinsic reward and was associated with the motivation to learn (Yoshida et al. 2008). The putamen, including the striatum, was strongly activated by sense of accomplishment, and putamen activation was positively associated with a motivation to learn score derived from a questionnaire (Mizuno et al. 2008). Academic rewards for motivational arousal include a sense of accomplishment and competence, self-efficacy, and acceptance by others (Deci et al. 1991, 1996). Perception of a good reputation by others is processed by the medial prefrontal cortex and the striatum (Izuma et al. 2008). These results suggest that the striatum plays a crucial role in the motivation to learn. Structural analysis of the brain in modern humans revealed that the motivation to learn score was positively correlated with the volume of the right putamen (Takeguchi et al. 2014), indicating that both the volume and the neural activity of the striatum are closely associated with the motivation to learn.

There is a negative correlation between the motivation to learn and fatigue, indicating that these phenomena are two sides of the same coin, and that accumulation of fatigue negatively reinforces not only motivation to learn, but also learning. The medial orbitofrontal cortex was associated with fatigue sensation using positron emission tomography (Tajima et al. 2010), and the activity of the medial orbitofrontal cortex, assessed using fMRI, increased with time spent on a fatigue-inducing task. In addition, activation of the medial orbitofrontal cortex was attenuated by the perception of an intrinsic reward, suggesting that intrinsic reward modulates the extent of fatigue alleviation.

To clarify the neural bases of motivation to learn and fatigue, we have determined what cognitive functions are correlated with the level of motivation to learn and/or the level of fatigue. When interpreted in light of the differences in brain morphology and function between modern and ancient humans, the neural substrates of these cognitive functions may provide information on the apparent differences in learning ability. In elementary and junior high school students, motivation to learn was associated with divided-attention performance, evaluated using the kana pick-out test (Mizuno et al. 2011a). Fatigue, which was evaluated using task E on the modified advanced trail making test (Mizuno et al. 2011b), was negatively associated with performance on the divided-attention task and with switching attention. Children and adolescents with chronic fatigue syndrome (CFS), which is characterized by profound and disabling fatigue for at least 6 months (Fukuda et al. 1994), showed poor performance on the divided-attention and switching-attention tasks (Tomoda et al. 2007; Kawatani et al. 2012). The ability to divide and switch attention dramatically develops from elementary

to junior high school (Mizuno et al. 2011c). These results suggest that motivation to learn and fatigue influence the age-dependent development of brain function. Using fMRI, we revealed that in young adults, the brain regions involved in the kana pick-out test are the left dorsal inferior frontal gyrus and the superior parietal lobule (Mizuno et al. 2012). Another fMRI study showed that the dorsolateral prefrontal cortex is crucial for the process of switching attention in the trail making test (Moll et al. 2002). A study performed using voxel-based morphometry demonstrated volume reduction of the bilateral dorsolateral prefrontal cortices in adult patients with CFS, and the reduction in volume in the right prefrontal cortex was associated with the severity of fatigue (Okada et al. 2004). Our recent study showed that the volume of the bilateral dorsolateral prefrontal cortices was also associated with fatigue in healthy adults.

These findings highlight the regions of the brain, including the striatum and medial orbitofrontal cortex, the medial prefrontal cortex, the inferior frontal gyrus, the superior parietal lobule, and the dorsolateral prefrontal cortex, that are of interest in relation to the motivation to learn, fatigue, and cognitive functions affected by motivation and fatigue in modern humans. Morphological and functional comparisons of these regions between modern and ancient humans are expected to help elucidate differences in learning abilities. We expect these outcomes to contribute to the achievements of the RNMH project.

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Reconstruction of the brain from skull fossil using computational anatomy

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We investigated the presumed differences in learning abilities between Neanderthals and Modern Humans by combining evidence from the morphological analysis of fossil brains and the functional mapping of Modern Humans' brain functions. Our study faced a fundamental challenge: although we could easily access the Modern Human brain data, the only available data for the Neanderthal's brain were skull or endocast image reconstructed from fossilized skull produced by Project C01. Hence, to achieve our purpose, we had to establish a method for extrapolating to human brain functions from skull or endocast anatomy, which is the only data available for both Modern Humans and Neanderthals. In our previous study, we developed a skull or endocast-based image registration method using the computational anatomy, which is a standard method such as functional MRI (fMRI) and voxel based morphometry (VBM) used in neuroimaging research (Kochiyama et al. 2014; Tanabe et al. 2014). This technique allows us to not only extrapolate the Neanderthal's brain that does not exist, but also to investigate the Neanderthal's brain morphology on the standardized stereotaxic space that is commonly used in the brain mapping community. Thus, the present study aimed at revealing a morphological difference between Neanderthals and Modern Humans. We quantitatively compare differences in patterns of regional anatomy using the multivariate analysis of deformation based morphometry (DBM) and automated anatomical labelling (AAL) parcellation-based morphometry.

We used three fossil skull CT images of Amud 1, Gibralar and La Chapelle-aux-Saints and 512 MR images of Japanese Modern Humans. All MRI images were acquired using a 3-Tesla MR scanner (Siemens, Verio) at the National Institute for Physiological Sciences (NIPS). A T1-weighted fine structural whole-brain image were acquired using a magnetization prepared rapid acquisition gradient echo (MP-RAGE). All of the subjects gave written informed consent for participation in the study. The protocol was approved by the local medical ethics committee at NIPS. Image processing was performed using the Statistical Parametric Mapping package (SPM8; Wellcome Department of Cognitive Neurology, London, UK), Surfstat (www.math. mcgill.ca/keith/surfstat/) and in-house software implemented in MATLAB (Mathworks Inc., Sherborn, MA, USA). First, we create endocast image as follows: For Neanderthal's data, the reconstruction of fossil endocast has already been explained in detail (Amano et al. 2014; Ogihara et al. 2014), so we will only briefly describe them. The fossil skull CT image was first isolated cranial fragments and then they were reassembled into the correct position. After approximated the cranial surface, the endocast was extracted. For Modern Human's data, we segmented individual MR images into the tissue probability maps of GM (gray matter), WM (white matter) and CSF (cerebrospinal fluid) by segmentation-normalization algorithm in SPM. Then, the sum of these segments image was threshold at the probability of 90 % to create the endocast image. The residual artifact cleaning with the removal of small isolated segments and filling holes was also applied to correct topological errors. Second, these endocasts were enter into Diffeomorphic Anatomical Registration Through Exponentiated Lie algebra or DARTEL registration algorithm to estimate a globally one-to-one smooth and continuous mapping between individuals well as between an individual image and a data specific template image. Resulting spatial transformation parameters describe the deformation field that encodes whole information relating to the position, size, and shape of the brain. Based on DARTEL, we conducted the quantitative comparison of brain morphology between Neanderthals and Modern Humans using two dif-

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ferent methodologies. (1) DBM is one of the multivariate analysis techniques, which is useful to detect structural differences over the entire brain because it analyzes positional differences between every voxel and a reference endocast. The Hotelling's T2 test can evaluate differences in the displacement vectors (i.e. the shape of endocast) between populations. (2) AAL (automated anatomical labeling) parcellation based morphometry (tentatively-named as PBM) was newly developed technique, which can evaluate the difference in regional brain volume over 116 brain regions defined by AAL. AAL scheme is an anatomical parcellation of the spatially normalized single-subject high-resolution T1 volume (Collin 27 brain) provided by the Montreal Neurological Institute (MNI). To calculate the brain volume in each of 116 regions for each individual, AAL map was inverse-transformed to each individual participant's native space by DARTEL transformation. The two sample T test was performed for each AAL region to evaluate the regional anatomical difference between populations.

Fig. 1 shows the result of multivariate test (left) for differences in the displacement vectors (right). The comparison of endocast between 512 Modern Humans and 3 Neanderthals showed a significant cluster spanning almost the entire posterior brain regions, including superior, inferior and posterior parietal cortices, occipital cortex and cerebellum. Small cluster was found in frontal and limbic regions. The small arrows in Fig. 1 (b) indicate 3D displacements needed to locally deform the Neanderthal's endocast to match it to the Modern Human's endocast. The arrows in cerebellum are long and inward mean large shrinkage in the Neanderthal's endocast relative to the Modern Humans. The shape change also occurred at the visual and frontal expansion and the parietal and temporal shrinkage.

Fig. 2 shows the result of the PBM. The left and right row indicates the comparison of AAL-defined volumes of interest between Modern Humans vs. Neanderthals (left), and Neanderthals vs. Modern Humans (right), respectively. Compared to Modern Humans, Neanderthals showed volume reductions of endocast in wide-spread areas of both parietal and cerebellum. The area of volume reduction was found in the lateral cerebellum, superior and inferior parietal lobule including angular and supramarginal gyrus. Neanderthals showed volume expansions compared with Modern Humans, mainly in the visual cortex. Volume enlargements were also found in the orbitofrontal cortices and limbic structures such as hippocampus. Visual inspection of Figs. 2 and 3 shows the similar local volume reduction/expansion patterns using a different methodology.

In this study, we found that the regional morphological difference between Neanderthals and Modern Humans in both the cerebral cortex and cerebellum using the computational anatomy approach. In future research, we will explore the structural-functional relations using a combination of the current approach along with the meta-analysis about social learning skills and creativity. Through ongoing analysis we hope to uncover the neuro-cognitive functions responsible for Neanderthal-Homo sapiens replacement drama.

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Modern human vs. Neanderthal

Fig. 1 Result of DBM analysis.

Modern human vs. Neanderthal Neanderthal vs. Modern human



Fig. 2 Result of DBM analysis.

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