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Data-Driven Anthropology

Exploring the Significance of Data and Digital Data Management Technologies

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Abstract

This work emphasises the synergy between anthropological research on human skeletal remains and suitable documentation strategies. Highlighting the significance of data recording and the use of digital databases in various aspects of anthropological work on bones, including scientific standards, skeletal collections, analysis of research results, ethical considerations, and curation, it provides a comprehensive examination of these topics to demonstrate the value of investing time and resources in this field, countering the existing lack of funding that has led to significant deficiencies. Additionally, the paper outlines the requirements and challenges associated with standard data protocoling and suggests that digital data management frameworks and technologies such as ontologies and semantic web technologies for anthropological information should be a central focus in developing solutions.

Keywords: Anthropology, human skeletal remains, digital data management technologies.

1 Anthropology

1.1 The Field's Potentials...

Anthropology is a complex field with a unique focus on holism. It aims at unveiling all aspects of the human condition, human behaviour, and interaction within a society and across different cultures from the past to present day (Ekezie, 2017), thus drawing from a multitude of disciplines from both the natural and social sciences (Hendry & Underdown, 2012).
That makes it hard to define or to distinguish from biology, sociology, or psychology for example, and therefore to clearly establish and locate it in the scientific landscape of some countries. Moreover, due to the high demands set by anthropology as a science in meeting the standards of scientific inquiry and following the scientific method, anthropological research can become a rather challenging task.
This is often the case where it concerns the study of bones, which constitutes a major part of physical – or biological – anthropology. Research on human skeletal remains allows for examination of the underlying causes and effects between humans and their environment. In this way it contributes important insights relating to issues of health and nutrition, population dynamics, social structure, and cultural systems (Orschiedt et al., 2011, p. 169). The knowledge thus obtained is important for the reconstruction of the past but also significant for contemporary issues, for instance when it comes to medical or medico-legal matters.
However, there are oftentimes several major problems preventing real, hard evidence from being gained.

1.2 ... And its Challenges: Major issues for scientific research on skeletons

One such difficulty is the relative scarcity of information that can be won from the skeleton. The reason for this scarcity is that bone can only react in a limited number of ways (Lockyer et al., 2011, p. 238). Consequently, the effects of the many possible causes may look very similar or even the same. In addition, there are various possible influences and forces that directly or indirectly act upon bone during one's lifetime, increasing to a myriad after death when the bone loses its protection by buffering body tissues. Since these influencing factors do not act independently and cannot be examined in a controlled experimental setting, identifying the exact nature of these interactions is an issue. Furthermore, as the human skeleton is subject to several kinds of variation, anthropological research results are to a great part population-specific. Add to the fact that every trace that can be found on the skeleton is a leftover of some event of the past which oftentimes cannot be explained by means of empirical investigation. Instead, possible scenarios need to be reconstructed and tested for their credibility (Mayr, 2002). Hence, with the precise ways of how bone responds to the environment not yet thoroughly understood (Rabey 2014, p. 42) as well as the possibilities for hypotheses testing being at least limited –sometimes even impossible – anthropologists find themselves delicately navigating between insights and plausible versions of what has happened. Nevertheless, there is "a perfectly understandable drive to make the most of what little evidence survives in the skeleton." Waldron (1994, p. 98). To be able to live up to this aim, anthropology has a strong methodological orientation. Yet, this alone is not enough. There is also "the need to include as much information as possible when interpreting" (Rabey, 2014, p. 284) features and findings.

Only a sufficient amount of information can (1) compensate for a lack of observation possibilities, (2) provide quantities of data large enough for analysis and the testing of hypotheses, and (3) make efficient use of new technologies and their potential for more detailed and exact diagnoses. Hence, with enough reliable data at hand, the number of possible explanations can be reduced so that, eventually, probabilities may turn into certainties – something which could possibly also attract more public attention, interest, and ultimately funding.

2 Data in Anthropology

Deductive reasoning enables scientists concerned with events of the past to "infer, from an observed effect, the preexisting cause or causes sufficient to produce that effect" (Belkin & Neelon, 1992, p. 863). In the process, it is important to take all kinds of details into account, and to observe, record, collect, and analyse even such features that may seem trivial or inconspicuous (ibid., p. 863 & 865). In this way, the work of every scientist concerned with the past – from the historian to the geologist to the archaeologist and anthropologist – is similar to that of a detective or diagnostician: "All observations pertinent to the case at hand must be discovered and assembled and then all must be linked, using known mechanisms and the laws of science, in a plausible sequence that extends into the unseen, but not unsurmisable, past" (ibid., p. 865). The emphasis set here on the imperative of adequate data collection and management in the form of databases for anthropology originates from several issues that are at the heart of anthropological practise.

2.1 Diversity of Information required in Anthropology as an Interdisciplinary Science

Being the synthesis of a number of natural and social sciences that address human oriented questions gives anthropology its strong interdisciplinary character. At the same time, anthropological perspectives are gaining an increasingly important role in other disciplines (Grupe et al., 2015, p. 1). Therefore, it has the potential to become the intersection and synergy of various sciences and humanities. But each field requires different kinds of data. Thus, to fully exploit this potential, it is fundamental to provide a wide array of different types of source material recorded with as much precision and detail as possible. In this way a great diversity of information "is merged…" (Sheridan, 2017, p. 112) and "a powerful tool for understanding the past becomes available, freed from the limitations of one perspective viewed in isolation" (ibid.). Consequently, each field would provide "… evidence for a larger … interpretation, both drawing from and contributing to the theories and interpretations of others" (ibid.). The practical solution would consist in accumulating as well as organising the whole range of information that relates to skeletal material in any way into a digital database. Such a database would guarantee transparency and access to research results (Grupe et al., 2015, p. 228). At the same time, it would form the foundation for crosscutting projects.

2.2 The Value of Data for Skeletal Collections and Research Results

Research focusing on core anthropological problems inevitably depends on skeletal collections. The value of a collection comprising skeletal remains in turn is defined by the quality of the scientific research conducted. Beyond this, the quality of documentation and the possibilities of its information retrieval determine how much insight can be gained. The more available verified information on the skeletal remains is, the more results can be validated. Likewise, well-documented original research facilitates the integration of its results into many analyses (Palkovich, 2001, p. 143). Therefore, subsequent research would greatly benefit from a database that unifies the data of various research topics, accumulated by either separate findings or large-scale projects (Engel et al., 2015, p. 3), thus forming the basis for more detailed, in-depth inquiry of the many interrelations affecting bone (Palkovich, 2001). The distinction between cause and effect may become blurred in anthropology for several reasons. First, the slightest influence may lead to changes in the condition of skeletal material. Second, the number of possible influences is seemingly endless, ranging from premortal and postmortal to taphonomic environmental factors to human actions and events beginning with the moment of discovery. Third, the traces found on the material are often ambiguous. One must systematically record all the data that can be obtained if one wishes to truthfully reconstruct what happened to the bone at all times and concerning all relevant aspects (Panagiaris, 2001, p. 96).

2.3 Extensive Data Recording as a Provision for the Future

The focus of research is shifting (Palkovich, 2001, p. 145) and technological possibilities are continually advancing, paving the way to more exact diagnoses so that new lines of inquiry arise over time. Anthropological study on bones increasingly seeks to contribute to contemporary issues (Buikstra & Ubelaker, 1994, p. 1). Further, the application of new technological tools may demand specific source material. Naturally, an important objective is to make use of past research outcomes and reanalyse them in a new context. For this purpose there needs to be a wide array of information available (Palkovich, 2001, p. 143). Therefore, the collection of data that is only relevant to the research question may have adverse consequences. With that in mind, it proves to be challenging - if not impossible - to say at the time of the recording what information is required and what can be left out.

3 Documentation and Digitalisation in Anthropology

3.1 High-Quality Documentation for Ensuring Adherence to Scientific Standards

Science aims at discovering the true nature of things, phenomena, and processes. Validation is a crucial method for substantiating the accuracy and scientific nature of research findings. To achieve validation, it is essential to ensure the objectivity of the research and its results. This requirement encompasses various aspects that must be adhered to at every stage of the research process. The outcomes attained by a scientific study or investigation must be reproducible by uninvolved researchers. At the same time, they must not be dependent on either the original setting or experimental setup. That can only be achieved based on a documentation that allows for both transparency and clarity. While transparency provides the data itself, clarity ensures that the whole project and its content is fully comprehensible to non-participant scientists. This greatly facilitates the comparability between different research works. A thorough documentation further

leads to traceability, thereby preventing important details from being overlooked as well as eventually lowering the risk of analyses becoming biased (Palkovich, 2001, p. 148). Taken all the above together, an even more profound effect could be reached: On the one hand, it may become possible to reduce the heavy reliance on the researcher's experience. On the other hand, the quality of the data recording may be improved. A clear and comprehensible documentation would inevitably involve instructions on what to record as well how to record it. Also,with such standardization, less-experienced individuals, such as trained students, could assist in the recording of data. As a result, it would be possible to record more details and to produce data that is both usable and credible.

3.2 Documentation and Digitalisation as a Foundation for New Dimensions ...

... for the Curation of Human Skeletal Remains

Bone is the linchpin of every anthropological inquiry regarding human skeletal remains. Without suitable skeletal material, all anthropological investigation becomes superfluous. For, if there is no bone, there is nothing to examine. Similar to a time capsule, a bone stores all information of the processes, occurrences, or forces that acted upon it in the past. Consequently, the informational value hinges upon the condition of the skeletal material available. The deterioration or destruction of the material inevitably leads to irretrievable loss of information, rendering any future research or review eventually impossible. Against this background, it is easy to tell how the quality of documentation can make or break the value of a skeletal collection. Ethical norms dictate to retain the remains only if the scientific interest and – as a consequence thereof – the scientific output outweigh moral and legal issues associated with the storage of human remains. There needs to be good reason not to lay the dead to rest without violating their dignity and right to rest in peace (Caffell et al., 2001, p. 196; Grupe et al., p. 19). Any action performed in relation with human remains needs to be justified, and it is through documentation that this can be attained. The same holds true for the preservation and conservation of the remains. Hence, curation must account for the collection, recording, administration, and retrieval of the whole scope of data and information regarding the work with and treatment of skeletal material (Grupe et al., 2015, p. 225). Indeed, that would imply a tremendous effort. However, the ensuing benefits would be similarly manifold and profound. First, a full inventory incorporating information of the available skeletal material itself as well as detailed background information would be established. By means of the latter, the bones could be connected to their various contexts (from excavation to storage, conservation, and curation effects, to condition assessments and examination, to name but a few). This vast pool of features and specifics comprising various formats such as field notes, protocols, maps, drawings, photographs, and samples of various kinds then can qualify to access and read the entirety of information preserved in bone. Still, these prospects can only be realized to their full extent once digitalisation comes into play. A digitised database has the critical capacity to join, store, and manage an immense if not potentially infinite amount of information from very different analogue formats. It also enables the researcher to retrieve and review all the data from one terminal device that may be both independent of time and location. As a result, it would be possible for researchers "to surround themselves with every shred of information about a collection or an object" (Palkovich, 2001, p. 148). Because of the enormous technological advances and advantages available through digitalisation, enhancing the forms, extent of detail, and accessibility of a documentation becomes much more feasible, thus playing an increasingly important role (ibid., p. 148). Digitalisation has the potential to make knowledge and material culture that is of public interest more available. Accordingly, easy and thorough accessibility is progressively becoming part of the demands made on curation facilities and research institutes by researchers as well as the general public (Grupe et al., 2015, p. 228). When documentation takes into account as many areas of interest as possible, it may serve as an indispensable decision tool where management and curation issues are concerned (Ahrndt et al., 2013; Janaway et al., 2001). An informative and comprehensible overview assists in selecting the respective appropriate care procedures or examination processes. For the latter, sampling is a typical example, representing an invasive procedure that requires sophisticated, well-informed concepts regarding sequence and extent of the samples if significant loss of information associated with the destruction of material is to be avoided (Grupe et al., 2015, p. 224). Constant monitoring with concomitant transparency and traceability is required in order to maintain the condition of elements (Caffell et al., 2001, p. 190, 194). Ensuring that skeletal material can stand the test of time means that the preservation of the remains must take top priority (Buikstra & Ubelaker, 1994, p. 2). The effects of use as well as of storage and handling practises lead to the deterioration of the material in the form of physical damage, material loss, mixed or falsely allocated elements (Caffell et al., 2001, p. 191). Hence, a lack of record keeping as well as of monitoring ultimately results in the loss of knowledge and depreciates a collection (Buikstra & Ubelaker, 1994, p. 2). By contrast, documentation that achieves to capture the complete process chain contributes to forensic anthropological evidence being approved for usage in court (Christensen & Crowder, 2009, p. 1212). Last but not least, an all-encompassing management of information is imperative so as to be able to adequately respond to ethical questions regarding provenance as well as deal with repatriation claims (Buikstra & Ubelaker, 1994, p. 2).

... as well as of Data Analysis

Yet, the effects of a digitised database are even more significant when it comes to the analysis of its content. Brought into a digitised format, data becomes suitable for electronic processing. This – together with the aforementioned volume of data that could be accumulated – (Körber, 2016, p. 24) would make the application of in-depth analytical procedures such as data mining possible. In this manner, the way is opened up to new dimensions regarding the production of anthropological evidence and the evaluation of its meaningfulness (ibid., p. 20). Although Locard's exchange principle known from forensic

science pertains equally for anthropology in the sense that every process leaves a trace on bone material, the real problem is that many traces either cannot be detected nor definitely allocated to their origin (Thompson & Scurich, 2018). In fact, as stated before, anthropologists frequently are faced with two kinds of evidence: One being ambiguous (the sort of evidence that could be the consequence of event A but also action B and sometimes even action C), and the other being no evidence at all, when the trace cannot be detected by examination. Consequently, inferences that can be drawn from these kinds of scientific findings tend to be all-or-nothing in character (ibid.). That is to say, they either lend support to definitive conclusions or fall short of providing sufficient evidence. What is missing is the in-between of these two extremes, namely the ability to capture and evaluate the inductive value of evidence that is probative without being absolute. It is possible to draw conclusions that are scientifically sound, however, through the combination of comprehensive data collection, statistics, and inference. The three aspects taken together can greatly enhance the ways to exploit all available cues and help access as well as decipher the knowledge stored in bone. The more information at hand, the more certain facts could be determined by logical deduction. In the same way, more hypotheses could be established that are worth consideration. Even more far reaching are the implications regarding inductive conclusions. Those are not necessarily true by nature but rather present a probability or plausible explanation, only one among other possible causes. Nonetheless, assessing how likely the concluded option is under the given circumstances confers substantial probative value to inductive inferences. Statistical approaches such as Bayesian statistics can, by drawing on precise and informative data regarding various circumstances, quantify and thereby objectively evaluate this degree of belief to which the evidence supports a particular hypothesis (Körber, 2016, p. 20). It is then possible to test hypotheses by comparing their likelihood ratios. In this regard, the judgement of plausibility extends beyond mere subjective gut feeling. All of this could greatly extend the researchers' leeway in the ways they can make use of their findings and explore new areas of research that were previously regarded as impossible.

4 Standards for Data Recording in Anthropology

A severe shortcoming of anthropological research is the lack of comparability between research projects due to the fact that researchers are accustomed to developing their own ways of collecting data, and studies are designed for very specific topics (Grupe et al., 2015, p. 228; Harbeck, 2020, Preface). Consequently, research results tend to be insular, more often than not confined to the context in which they were created (Buikstra & Ubelaker, 1994, p. 3). The need for efficient and practical data recording procedures has long been acknowledged (Giesen et al., 2013, p. 61). Important work regarding the topic has been done at least since the mid 1990's. At that time, American anthropologists were faced with potential repatriation claims of human remains emerging in the wake of preceding laws, which mandated that the fate of a collection encompassing human remains was to be determined by their descendants (Buikstra & Ubelaker, 1994, p. 2). It was against this backdrop that Buikstra and Ubelaker (1994) published a compilation of guidelines developed by leading experts in anthropology that had the purpose of serving as a guideline for uniform minimal data collection. Since then, further standardized data recording protocols and corresponding software have been proposed (Brickley & McKinley, 2004; Connell & Rauxloh, 2012; Dudar & Jones, 2011; Harbeck, 2020; Jantz & Ousley, 2005; Langley et al., 2016; Mitchell & Brickley, 2017; Ousley & Jantz, 1998, 2012; Powers, 2012; Steckel et al., 2006 (Revised 2011); Trautmann, 2020; White, 2006; Wilczak & Dudar, 2012). The word "standard" might be misleading, though. When a standard is established, the motivation behind it is to create a common ground on which the work is done. A standard is the only way to assure reliability and comparability independent of context or subjective influences. It further assists in getting the most out of an activity since every standard requires a well-thought-out concept pooling suitable methods and procedures as well as assembling them with focus on quality, practicability, and scope. Thus, standardisation may be considered as a premise for state of the art. Therefore, a standard should also be universally applicable. Yet, in anthropology, the existing standards are tailored to the research goals, core areas of interest, and the methodology of the institutions that designed them, in addition to the purpose, use, and scope of their collections. These factors vary by institution, sometimes to a great extent. Especially in respect of the choice of methods, the level of consensus within anthropological circles tends to be rather low. As a result, different practitioners use different methods according to varying assessment criteria so that the standards either remain confined to the internal level or may only partially be adopted by external workers (Engel et al., 2015, p. 3; Harbeck, 2020, Preface). This is demonstrated by the great number of existing standard proposals that were all developed as an attempt to overcome the incompatibilities of the previous ones (Engel et al., 2015, p. 2). Although the localised protocols obviously confirm that a standardized solution really is much in demand (Giesen et al., 2013, p. 55), the creation of a centralised database with a cross-institutional if not national or even international outreach that is based on a universal standard is a challenging endeavour due to various obstacles, the most prominent of all being lack of appropriate funding. Associated with this is the lack of adequate resources, qualified staff, and time. Moreover, these problems are mirrored in the quality of the micro-level standard guidelines, evident in their range, level of detail and the frequency of updates. Leaving the technical requirements aside, standard terminology "standardly applied" (Buikstra & Ubelaker, 1994, p. 108) forms the core prerequisite for a database that can be employed widely. At the same time, it represents the main reason for incompatibility between existing standards. A terminology of that kind needs to be unambiguous and precise in such a way that anyone with adequate training but otherwise unfamiliar with the remains recorded would be able to get a clear picture regarding such relevant features as location, distribution and so forth (ibid., p. 108).

Furthermore, in order to form consistent data sets, the terminology ought to be consistent (Harbeck, 2020, Preface). Unfortunately, that easily leads to the terminology becoming rigid. However, it must be equally flexible and expandable so that it can be made suitable for specific situations (Palkovich, 2001, p. 146). Identifying the set of criteria required is a matter of common sense and is quickly done. The real problem and main challenge for the categorisation of data in anthropological research on human remains is to fully realise each criterion in light of the immense diversity of possible aspects relevant for analysis and interpretation. Moreover, it can be very difficult to record a feature's expression in an objective way that is comprehensible for outsiders using only categories. The constraints of categorization – most importantly the clear boundaries between the individual categories – often prevent a realistic depiction of the aspect recorded. This is the reason descriptive narratives are still an indispensable element for the documentation of human remains (ibid., p. 145). They can much better capture the details that are more nuanced and lack clear-cut distinctions between distinct characteristics. Meanwhile, data categorisation still leaves a lot to be desired, as numerous attempts have shown (ibid., p. 145). Given the advancements in natural language processing (NLP) and machine learning techniques, AI has made free text descriptions increasingly viable and valuable (Boer et al., 2023; Westhofen et al., 2022). However, to fully leverage the potential of these technologies, it remains crucial to develop and employ effective "strategies for codifying, recording, and mining the data" (Palkovich, 2001, p. 148).

5 Ontologies, Databases, and Semantic Web Development in Anthropology

A working digital data management framework or technology such as an ontology is the pivot of any such digital strategy. As the basic component to any database, the ontology depicts an outtake of the real world in the form of concepts and categories so that information can be stored digitally in an efficient way (Gruber, 1995). If designed in a modular manner, it is also easily possible to expand the existing concepts by adding new components to suit the needs of processes which require data types not yet included in the ontology. Defining such an ontology could be done using the three-ontology method which only requires adding the domain-specific knowledge to already existing ontology structures (Hoehndorf et al., 2009; Loebe et al., 2022). In this way, an ontology could improve communication between scientists by declaring and unifying fixed terms and definitions for anthropological knowledge, since terms can vary greatly among different institutions (Engel & Schlager, 2019). Once the core concepts are declared, these can form the basis of an anthropological database system which in turn allows an easier integration of anthropological data for research projects or in the development of software aimed to assist anthropological research such as statistical analysis tools, 3D viewers (Heuschkel et al., in proc.) and even AI models that use anthropological datasets for training. The prerequisite for such usage in software development is a database with an implemented API to allow access to the stored datasets through code. The database system could also enable easy access to anthropological data provided by institutions around the globe while ensuring data ownership through flexible access rights configuration and copyright adherence. Having such a system in place also allows for the implementation of advanced processes like automatically filtering and exploring data through software agents or using the datasets with AI models assisting research and education in anthropology – e.g., generating guides for osteometric measurements through an application similar to ChatGPT (OpenAI, 2023) or helping in data analysis, pattern recognition, or decision-making. A tangible example is given by a recent study (Kun et al., 2023) employing AI to extract bone length measurements and explore correlations between genomic regions and proportions, enabling the examination of bipedalism's genetic basis. The training of such AI models could also be realised with free text descriptions as they are common in anthropology, but the results may be inaccurate, depending on the number and type of datasets used. An ontology as a basis would allow defining a fixed structure for the knowledge accessed by the AI model, reducing the amount of data needed for training. To sum it up, having access to a database system for anthropological data could improve the quality of research by providing an increased amount of data to address the problem of narrowing down the probable explanations for traces, including datasets that were yet unfamiliar, enabling the development of further research software and provide a simple solution to archive and publish original datasets complementing research papers.

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