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Authors
de Voogt, Alex
Maillot, Marc
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et al.

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Cultural transmission of architectural traits: From the Near East to the Meroitic kingdom

Alex de Voogt[a,*], Marc Maillot[b], Jonas W.B. Lang[c], Jelmer W. Eerkens[d]

[a] Department of Economics and Business, Drew University, 36 Madison Ave, Madison, NJ 07940, USA
[b] Section Française de la Direction des Antiquités du Soudan Ambassade de France Khartoum (Soudan) Service de la Valise diplomatique, 13 Rue Louveau, 92438 Châtillon Cedex, France
[c] Department of Personnel Management, Work and Organizational Psychology, Ghent University Henri Dunantlaan 2 9000, Ghent, Belgium
[d] Department of Anthropology, University of California, Davis, CA 95616, USA

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ABSTRACT

Architecture is a complex cultural trait that lends itself to the analytical methods developed for cultural transmission theory. We analyze a dataset of palace structures that gives insight into horizontal transmission processes between Sudan, Egypt, and the Near East during the Meroitic and Greco-Roman time periods. High similarity between buildings in the same region suggests that building activities required social coordination between builders, as predicted by cultural transmission theory. Similarity in the expression of coating layers and coating thickness both within and across regions also confirms that the iconicity of palaces correlates with the dominance of prestige bias during transmission. Finally, similarity in bricks, mortar, and coating ingredients between buildings in the same region, but significant variation across regions, confirms the prediction that building materials are locally sourced. Results establish a baseline of horizontal transmission for architecture more generally, contrasting traits associated with the outer appearance of buildings, versus those less visible and related to construction design. Additional studies of different regions or with a diachronic perspective may show if hypotheses about the cultural transmission of architecture can be generalized across time and space.

1. Introduction

Cultural evolutionary theory (CET) provides a framework for understanding human behavioral change. CET commonly includes modeling and quantitative analyses and is informed by disciplines ranging from psychology and economics, to biology and archaeology. Cultural transmission (CT) theory is a particular body of theory within CET, and provides a conceptual framework for understanding how cultural information, or traits, are exchanged and/or modified between individuals and/or groups (Mesoudi et al., 2006; Henrich et al., 2008). Most CT models examine the role that various factors have on the transmission process, such as the context of transmission events that includes environmental factors, the content of the information (i.e., the nature of the cultural traits, for example, simple or complex information), and various biasing mechanisms that may be in place (e.g., prestige, production or conformist biases).

Archaeological applications of CT have concentrated on functional items (e.g., projectile points, pots, baskets) or stylistic elements (e.g., decoration) at least in part because of the availability of quantifiable datasets, and have tended to focus on items used by single individuals within small-scale societies (e.g., Bettinger and Eerkens, 1999; Henrich, 2004; Jordan and Shennan, 2003; Kohler et al., 2004; MacDonald, 1998; McClure, 2007; Shennan and Wilkinson, 2001). Producers and users have the ability to experiment and modify these cultural traits before retransmitting information about them to others. However, recent studies have sought to expand this focus to include objects that are inherently used by two or more people (de Voogt et al., 2013), thereby complicating the transmission process, and to examine CT within the context of (city) states as opposed to small-scale societies (Eerkens and de Voogt, 2018). In this study, we continue the latter trend and focus on CT of architectural traits within state-level societies of Sudan, Egypt and the Near East.

2. Previous research on CT of architecture

CT of large-scale architecture commonly takes place in state-level

* Corresponding author.
E-mail addresses: adevoogt@drew.edu (A. de Voogt), mmaillot4@yahoo.fr (M. Maillot), jonas.lang@ugent.be (J.W.B. Lang), jweerkens@ucdavis.edu (J.W. Eerkens).

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societies and includes multiple individuals who are part of the transmission process. Different individuals are typically responsible for various aspects of the construction process, such as the brick-making or laying. Each individual will have learned their craft within a distinctive learning environment (e.g., apprentice vs. textbook), with a unique history in the development and transmission of knowledge. In addition, each individual will have their own trial-and-error and skill-building history. The local environment is likely to influence the final product as well, for example, through the choice of specific local building materials or the slope and aspect of the building location.

In 2015, Cochrane used a cladistics analysis to understand the similarities and differences of parts of architecture that are likely to be a result of CT. He used the presence-absence of characters to classify Polynesian religious architecture (Cochrane, 2015:18), but found almost no clear phylogenetic patterns or specific lineages of CT. He identified a number of possible explanations for this result including: (1) high innovation rates resulting in many observed character states; (2) high levels of horizontal trait transmission; and (3) taxa definitions that do not generate variation associated with phylogenetic relationships when analyzed with cladistics (Cochrane, 2015:37).

Multi-state characters as opposed to traits that are merely present or absent may provide character-state distributions that point to innovation rates, but what would drive such innovation in architecture and at what cost (see e.g., Fitzhugh, 2001)? Kandler and Laland (2009) link innovation rates with cultural diversity. In this respect, for the derivation of more general principles regarding CT of architecture, Polynesia is not an ideal testing ground, as the degree of cultural variation within Polynesia is low when compared to many other regions.

By contrast, Greenhill et al. (2009:2302) have shown that phylogenetic methods applied to studies of cultural evolution are not necessarily invalidated by "realistic levels" of horizontal transmission, or as they put it: "The crucial question is, of course, what scenarios of horizontal transmission are most realistic." They maintain that (Greenhill et al., 2009:2303) "Most published language/culture phylogenies have followed a procedure of removing obvious borrowings before analysis." Unfortunately, in the case of architecture there is no simple technique or baseline dataset to define what is obvious borrowing. Furthermore, the architectural traits used by Cochrane, such as the design of courtyards and placement of altars, were predominantly visible features as opposed to less visible elements of construction technique or the source of construction materials. This is significant because previous research has shown that different traits within complex technologies may be subject to different CT processes and evolve at different rates and in different directions (Bettinger and Eerkens, 1999; Eerkens and Lipo, 2005, 2007).

While Cochrane's study of Polynesian religious architecture provides a useful point of departure for studying CT in architecture more generally, identifying more varied and multi-state characteristics for architecture across more strongly diversified culture groups is an important direction for future research. As well, establishing a baseline of horizontal transmission for architecture more generally will require an investigation of the process across multiple regions and a range of time periods. To help fill this gap, we compared palace architecture across three culturally distinct regions, Sudan, Egypt, and the Near East, focusing on a single time period. We sought architectural elements that vary on a nominal scale rather than binomial (presence vs. absence). We use CT theory to formulate predictions about how such elements ought to vary, considering both environmental factors and CT biasing mechanisms.

2.1. Cultural transmission and the palace

The details and complexities of CT theory are outlined in several recent studies (e.g., Mesoudi et al., 2006; Henrich et al., 2008; de Voogt et al., 2013). For the purposes of studying architecture, we focus mainly on horizontal transmission, or transmission of information between peers or peer groups, rather than vertical transmission between generations. In other words, we focus on synchronous variation in palace architecture, rather than diachronic change.

If horizontal transmission dominates, then similarity in cultural traits should be related primarily to the intensity of contact or trade between peer groups. In most pre-industrial contexts, this should typically correlate to geographic proximity. The regions selected for our study on architecture are neighboring and part of a tradition of exchange between separate individually coherent culture groups.

A number of biases have been examined within such horizontal transmission processes, including conformist, prestige, and production biases. Such biases are particularly important where individuals or groups have a choice of potential models to copy. They may choose, for example, the most common type (conformist), the types used by high status groups or individuals (prestige), or the type that is dictated by interaction with the material and tools in use (production). In the case of palaces, the copying of prestigious examples of neighboring groups is expected to dominate.

Some packages of information may also be passed together in which case architectural elements become linked (e.g., Mesoudi and O'Brien, 2008), for instance building materials and building techniques, or the ingredients used for bricks and mortar. In a complex cultural trait such as architecture, we expect that this is often the case.

Finally, ecological factors may lead to local innovations that are similar from one group to another, without the existence of contact or exchange between those groups. Such analogous traits may emerge to solve a common architectural problem, but with different local solutions. Since architecture includes sourcing of raw materials, ecological factors may explain certain differences and similarities between the ingredients of these materials.

2.2. Predictions for architectural traits

Our comparison is based on architectural traditions found in the Sudan for the Meroitic Kingdom, which existed between ca. 350 BCE and 350 CE. In the Near East and Egypt, this time frame corresponds to the Greco-Roman period. Egypt and the Near East were brought under the same rule during the conquests of Alexander the Great in the fourth century BCE, followed by the conquest of the Roman Empire from the first century BCE onwards. Regular contact between Egypt and the Near East suggests that cultural exchanges also should have regularly taken place, while the Meroitic Kingdom remained relatively isolated from or in defiance of these northern forces (Török, 2009).

Architecture, and more specifically palaces, is likely to be affected by both ecological factors, due to the availability of various building materials, as well as prestige biases, due to the iconicity of the final result. Because of the costs associated with transporting heavy materials such as stone, mortar, brick, and coating, these materials are typically derived from local sources. As such, they are more likely to vary over space, and independent of one another, regardless of cultural affinity. In contrast, brick production (including brick size) and brick laying techniques are not dependent on local source materials, but more likely to be influenced by sharing of cultural information. As a result, these traits are likely to be transmitted over time and space with greater fidelity. These traits are also more likely to "piggy-back" and be transmitted together as a package from one group to another.

In this study, we examine the degree to which these different traits vary over space, and with respect to one another, in order to examine the mechanisms of ancient CT. We expect a greater degree of homogeneity within a cultural region, with less across regions, especially in Sudan. We concentrate on palace structures, which are likely to be influenced by a prestige bias. We also contrast traits associated with the outer appearance of buildings, versus those less visible but related to construction design. For example, coating layers and coating thickness are most visible, while brick-laying technique is only noticeable after dismantling a structure.

In light of the discussion above, we propose the following hypotheses:

Hypothesis 1a. Building activities require social coordination between builders leading to high similarity between buildings in the same region.

Hypothesis 1b. The iconicity of palaces is expected to correlate with the dominance of prestige bias during transmission. As a result, we expect high similarity in the expression of coating layers and coating thickness both within and across regions.

Hypothesis 1c. Building materials are locally sourced leading to high similarity of bricks, mortar, and coating ingredients between buildings in the same region, but greater variation across regions.

2.3. The palace

In modern English, a "palace" is defined as the official residence of a sovereign or exalted person. In archaeological cases, this specific cultural context can be difficult to demonstrate (e.g., Naumann, 1971:389, Fenasse, 1960:977, Corswant, 1956:234, Barrois, 1939:277). Instead, we rely on particular archaeological associations to classify an ancient building as a "palace" or not.

In the archaeology of Sudan, Egypt, and the Near East, an ancient palace is defined based on a combination of indicators that arise during an excavation. In some cases, the building may contain inscriptions mentioning its name, its destination, or the name of the sovereign responsible for the construction. Occasionally, the material can also supply the name of other, later, sovereigns, pointing to the sustainability of the building and possible reorganization and reuse. The general function of the building can then be deduced with a sufficient degree of certainty. When the building does not contain epigraphic indications, archaeologists often use materials retrieved from inside the building as well as features of the architectural monument itself to help determine if it was a palace. Occasionally, identification is obvious, as when the building contains artifacts with the name of a particular individual or sovereign. The richness of the decor and the quantity of material found inside usually does not suffice.

Palaces also lack features with known ritual and sacred functions that other building types, especially temples, typically display. The complexity of these distinctions is illustrated with the Meroitic building M998 (Hinkel and Sievertsen, 2002: 138), which was identified as a palace due to its dimensions, alternatively as a store considering the elongated and narrow rooms framing the central space, and finally as a potential "treasury" because of its implementation in the city center. Similarly, M950 contains artifacts, such as faience amulets in the shape of the ram-headed God Amun, a lion and an udjat-eye that were identified as religious (Hinkel and Sievertsen, 2002: 131–132), but it was noticed afterwards that this material was not reserved for a sacred domain.

While we apply specific criteria within this study to define a building as a "palace", we acknowledge that our classification system is somewhat arbitrary. Some palaces could simply be large residences of non-exalted individuals. Such complexities have been recognized by others, for example, in Late Antique Sudan (Hinkel & Sievertsen, O'Connor, 1989: 81–82). Palace buildings are not invariable, do not contain systematic features, and even if they have a common plan, the features do not apply to the entire set of buildings (see Fig. 1, Fig. 2a–c). We prefer to keep the term "palace" without attributing a precise cultural meaning. Although a more general term such as "monumental residence" could be considered, such a renaming would require further discussion in the literature of each of these regions. In sum, and as discussed below, we define palaces by cross-referencing all factors and available data, including the dimensions and thickness of walls, floor space, epigraphy, symmetry, recurring functional elements, positioning of the structure on a site, and artifacts and features contained within the buildings.

2.4. Mortar and plaster coating

The technical details regarding mortar and plaster composition are only partially represented in our palace dataset. The mortar, vertical joints, and plaster should be understood as follows (see also Figs. 3 & 4): Mortar normally forms a bed beneath each new course of bricks and between each brick. Vertical joints tend to be narrower than horizontal joints. The mortar is often of a similar composition to the mud bricks themselves, only more water is used in order to make the mixture spreadable, and it is often less rich in vegetal temper. Standard vertical joints measure 1–2 cm, while standard horizontal joints measure 2 cm on average (sometimes 3). Mortar is similar to the mud bricks in that it is usually brown in color and often has organic inclusions, such as seeds and charcoal parts. Non-organic inclusions, such as small pebbles and ceramics, are present in many cases as well. Finally, plaster is a significant structural and decorative attribute of buildings in the period under study. The plastering process was fairly uniform and plaster application was a simple process, with the greatest variation occurring in the number of layers applied.

The application of plaster consists of multiple stages. Plaster is typically comprised of a primary base coat consisting of a mixture of mud and straw (the latter being sometimes replaced by another degreaser), and applied to the mud bricks to provide an even surface. The following two stages are optional but often found in palaces. Following the mud plaster, a rough gypsum plaster (or lime plaster, the difference is rarely recorded in the literature), with small inclusions of yellow, brown, and black sand, could be applied onto the mud bricks. This preliminary layer was allowed to dry, and a finer coat of gypsum/lime plaster could then be applied on top to give a fine, smooth finish. This second coat of gypsum/lime typically has smaller and fewer inclusions and was very thin (1–2 mm thick). Finally, after the wall surface with its base coat of gypsum/lime plaster was prepared, it was painted with pigment. The most common painting techniques across the Roman Empire were tempera and fresco. The tempera technique involves working on a dry surface, which requires pigments to be mixed with some form of liquid binding medium, such as egg white, animal glue, wax, or vegetable oil to form a paint, allowing the pigments to adhere to the wall. The tempera technique is best for painting quick-drying clay-rendered walls (for this reason it is also often referred to as painting a secco). Due to the arid climate, most wall paintings are of the tempera variety.

There are three different types of plaster used in standard plastering processes: (1) mud plaster, (2) gypsum/lime plaster, and (3) painted plaster. First, the walls were covered in mud plaster in various states of preservation. Mud plaster is a significant attribute of the mud brick walls because it aids the appearance of the wall, helps protect it against weathering, and adds mechanical strength. Plaster often differs from mortar in that it has a higher concentration of straw (or another degreaser that has been selected), which reduces cracking. Unfortunately, such plaster also degrades faster, as insects consume the straw creating cavities that render the plaster friable, and causing it and any overlying plaster to separate from the wall. Second, gypsum/lime plaster served as both a stand-alone white plaster as well as the preparatory surface on which many pigments were applied. Gypsum plaster is frequently found in Romano-Egyptian structures and is composed of gypsum (hydrated calcium sulphate $CaSO_4{\cdot}2H_2O$) and anhydrite (anhydrous calcium sulphate $CaSO_4$). Data suggests that the majority of walls had a bare mud plaster with patches marking areas that had been repaired or re-plastered due to wear.

2.5. Bricks

Brick making is one of the oldest practices in antiquity, and today sundried bricks still are the most common building material. Bricks are usually made of Nile alluvium, which is essentially a mixture of clay

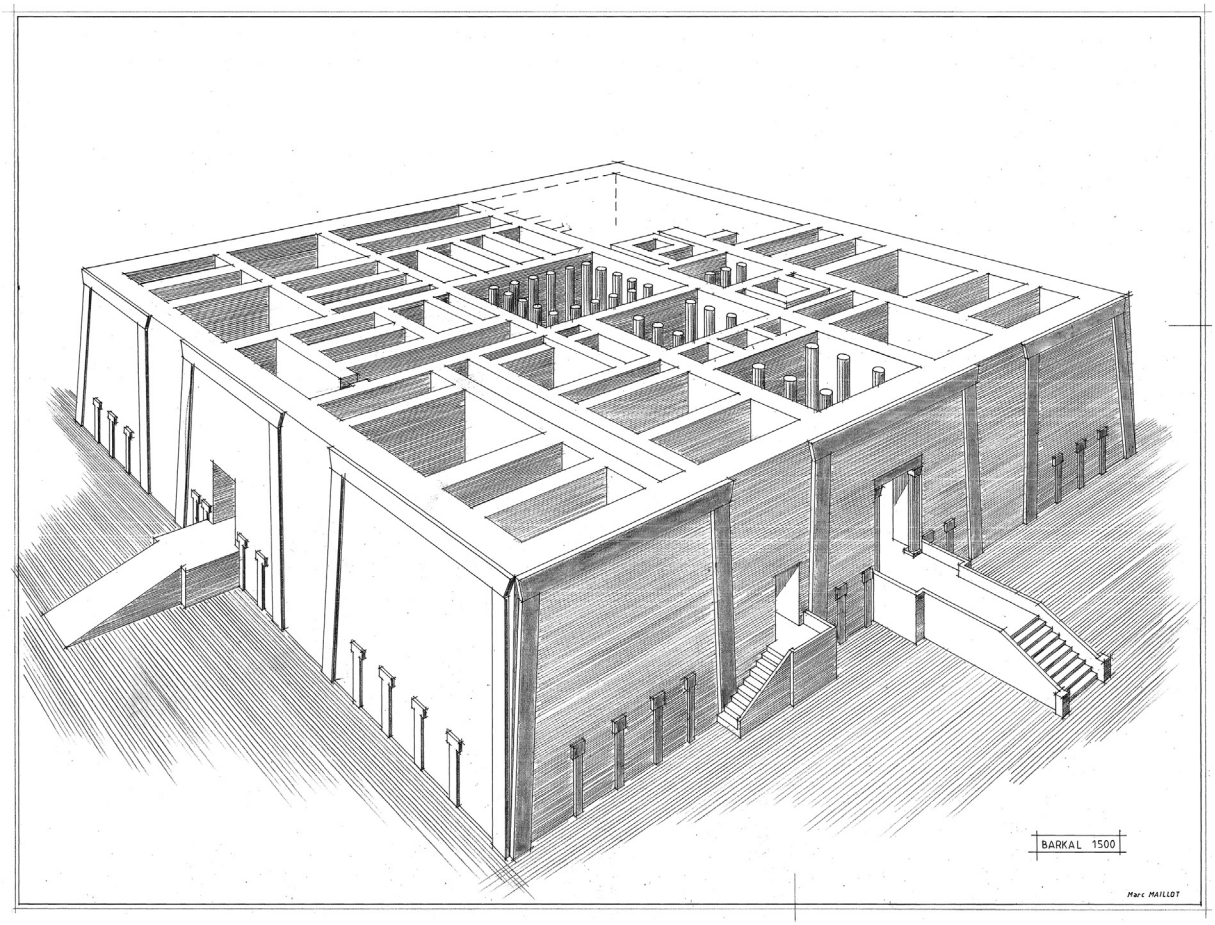

Fig. 1. Reconstruction of a palace for B1500 in Djebel Barkal (Sudan). See also Fig. 2 for a plan of this structure. ©Marc Maillot.

and sand, containing small amounts of impurities. The relative proportions may vary according to the geographical environment, but the quality of the clays remains the key element for the plastic and cohesive properties of the mud (Goyon and Golvin, 2004). The percentage of clay must be high but not too rich, because it slows down the drying process, and provokes cracks and shrinks into the brick. To prevent this, the mud is mixed with sand, chopped straw or any other kind of degreaser (e.g., pebbles, charcoal, bones, donkey dung) to reinforce the internal structure of the bricks, and strengthen their mechanical binding.

The method for making bricks is well known from the Egyptian Middle Kingdom onwards, and is almost identical to the present-day process (see Figs. 5 & 6). Hard mud is broken up with a hoe, mixed with water, and kneaded with the feet until it reaches the right consistency. It is then carried to the workshop, where the mud is shaped by means of a wooden mold. It is then lifted out, leaving the brick on the ground to dry in the sun. The method does not require extensive skills, the material cost is low, and the approach is perfectly adapted to a hot and dry climate.

The format used for ordinary bricks is almost exclusively rectangular. This standard measure facilitates the estimate of the volume and thereby the number of bricks needed for construction. The length commonly corresponds to twice the width. The ratio of length-width-thickness is usually 6:3:2. In addition to its parallelepipedal volume, the size of the brick must also meet practical requirements such as transport and handling. It should be easy to carry by one person and handled without too much effort. The limitation of its volume is thus linked to pragmatic concerns such as weight and maneuverability. The archaeological examples discussed in this study, for instance, do not have brick lengths > 40–45 cm. The standard size is adhered to systematically, and in Sudan corresponds approximately to 35 × 18 × 8 cm (plus or minus 1 cm for each measurement), a relative application of the ratio identified above. In order to ensure the implementation of particular architectural elements, such as vaulted roofing, specific shapes have sometimes been made for more circumscribed applications in construction.

The baked brick is a strong marker of late period construction, especially from the second half of the 1st century CE where it appears regularly in foundations. Because of its resilience in wet conditions, the fired brick is the preferred material for spaces in direct contact with water and hydraulic installations, such as pipes (water supply and drainage), wells, and cisterns. The mechanical qualities of the fired brick also make it an element usable in non-hydraulic architecture where it offers a compromise for the substitution of stone. Its superior resistance to compression and friction explains a use for the sensitive parts of the construction subjected to the pressures and pushes (e.g., framing of the doors and windows, reinforcement of the angles) or the phenomena of wear and erosion (e.g., floors, thresholds, steps). The fired brick is also used in the lower parts of the walls to strengthen the foundation of the building. Finally, its refractory qualities and its thermal resistance make it advantageous for the construction of combustion structures, whether it is domestic furnaces or heating systems.

During construction, bricks are arranged continuously on the same course and along the entire length of the wall before the next course is laid (see Fig. 7). The building of a wall may be preceded by a leveling course with bricks on edge to compensate for an uneven ground level. Although they are probably present in many of the structures mentioned here, they have not been systematically recorded and only occasionally received attention (see Maillot, 2016). Bricks are jointed with a mud mortar of variable composition, generally close to the one of the brick, and stabilized with sand and other degreasers. It could be

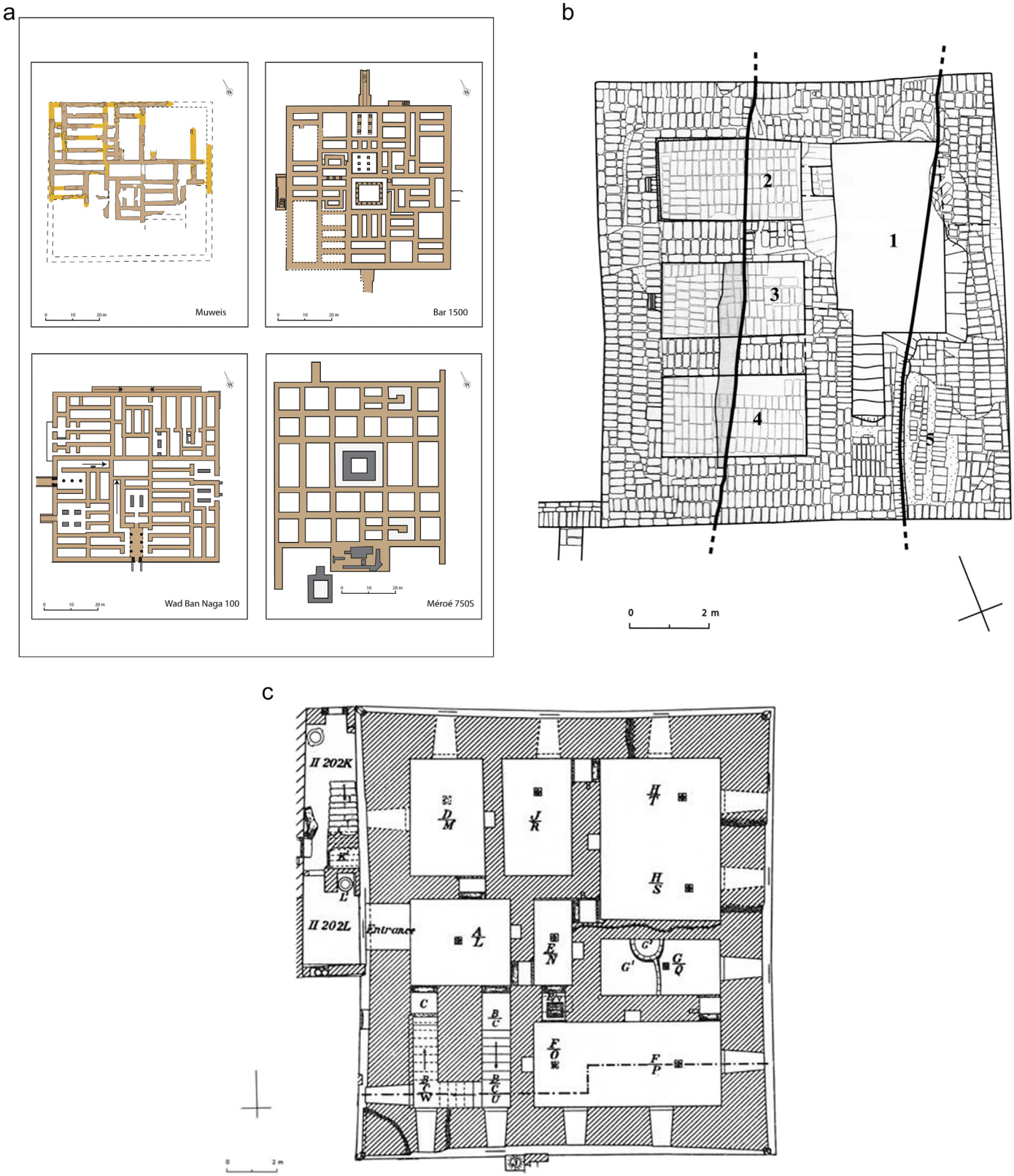

Fig. 2. a. Meroitic palaces of Muweis, Bar 1500, Wad Ban Naga 100 and Meroe 750 (Sudan) ©Marc Maillot.
b. Tell el Herr, Tower House (Egypt), from Valbelle (2007).
c. S. Nesos II-201 (Egypt), from Boak (1935, plan IV).

very wet, although never liquid, but mostly of a semi-soft texture to easily adhere to the bricks, and lay flat on the entire surface of the brick. The joints generally have a thickness of one to two centimeters maximum, a greater thickness causing a weakening of the wall. The cohesion of the bricks is mostly ensured by an alternation of headers and stretchers, a particularly common method that is observed

Fig. 3. Detail of a palace wall at Wad ben Naga (Sudan) presenting the layers of mud mortar between the bricks. Some mortar voluntarily overflows on other courses to reinforce the cohesion of the wall (© Marc Maillot).

Fig. 4. Lime plaster at Wad ben Naga palace (Sudan) ©Marc Maillot.

frequently on the outside of the walls. This brick-laying method aims to respect the fundamental principle of the non-superposition of two vertical joints. With this alternation, the joints cross systematically and the bricks are connected between them. This technique avoids internal cracking and minimizes the weaknesses and breaks by ensuring a better distribution of loads. From one header course to another, the builder could make a quarter of brick shifts or introduce halves or even fragments of a brick so that on three successive courses, the joints are never located on the same vertical axis.

Square bricks or the use of just headers are not entirely absent from archaeological examples. In this case, bricks are sometimes shifted from one course to another, moving a quarter or a half-brick that allows the non-superposition of the joints. Even if the wall facings respect the alternation of headers and stretchers, the bricks inside the masonry could have variable configurations from one wall to another, depending on the demands of the masons or of the structure itself (e.g., constructions of an angle, basement, vault). This is why in this study the measurements for each part of the construction are separated, as they are often the only remaining clue of a room function available in the archaeological documentation.

3. Materials and methods

We confine our analyses to attributes of buildings that are 1) consistently recorded by the archaeologists in the three regions, 2) present in buildings in all three regions, 3) are quantitative in nature. These constraints ensure that our comparison between regions is less influenced by idiosyncratic or subjective observations by archaeologists, as excavations in these regions have been conducted by a range of professionals under various archaeological traditions. Further, we selected

Fig. 5. Luxor Temple, 1988 (from Goyon and Golvin, 2004, Fig. 80).

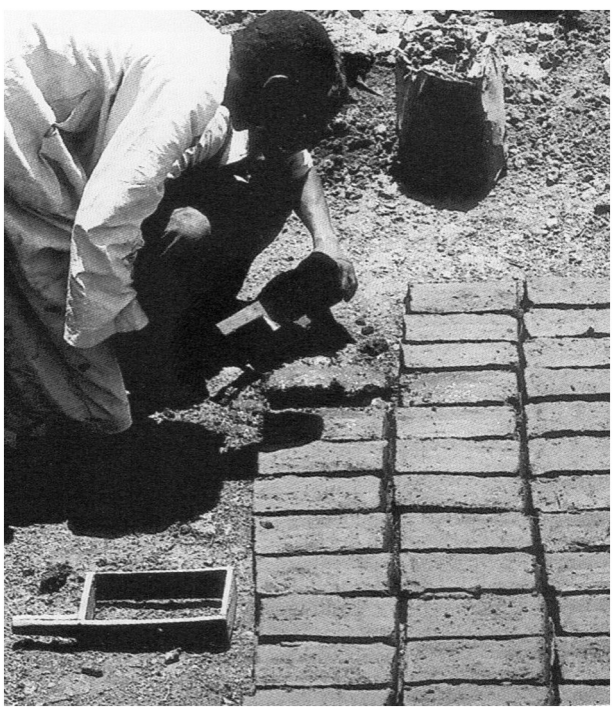

Fig. 6. Brick mold, with handle (from Goyon and Golvin, 2004, Fig. 84).

building attributes for which local expressions are possible but not necessary. It cannot be overstated that this is only a selection of all possible attributes that give a first indication of the CT processes at play.

In order to facilitate our comparisons, we took the following steps. First, we concentrated on one type of building type — the palace. Not only are palaces present in each of these areas but they have received much attention from archaeologists. Detailed plans and excavation reports have been published and a sufficient number of these buildings is present in each of these regions for the studied time period to make a comparison statistically meaningful.

Second, we selected aspects of the architecture that were consistently reported in all three regions and for all parts of the building. Since it is possible that different architectural materials or techniques were applied to different parts of the building, the traits needed to have been reported for all structural elements of a palace: floor, wall, basement, foundation, courtyard, casemates, storage, and access features, if applicable.

Third, we made sure that there was a combination of aspects referencing building material and techniques, each of which is possibly influenced differently by region and culture. Materials were identified for the brick, mortar and coating and sizes were documented for two types of bricks—fired bricks and mud bricks. Techniques were addressed by looking at the number of coatings, the laying patterns of the bricks, as well as the thickness of mortar and coating.

The complete dataset consists of three regions (Near East, Egypt, Sudan) with fifteen palaces each (see Table 1). Within each palace, the floor, wall, basement, foundation, courtyard, casemates, storage, and access features were each coded for brick material, mud brick size, firebrick size, brick laying technique, mortar type, mortar thickness, coating type, coating thickness, and number of coating layers. In other words, the dataset includes 3 (regions) × 15 (palaces) × 8 (structural elements) × 9 (attributes), for a maximum of 3240 individual observations (i.e., 72 data points per palace). Of course, not all these data points were present in each palace, especially in the Near East, resulting in some missing data.

As a result of the varied archaeological traditions as well as the absence of data on several other possible aspects of architecture, some caution is required with the interpretation of the data. First, the relative homogeneity of the data on brick size, for instance, is partly the result of imprecise measurements and descriptions. The presence or absence of variation is based on published measurements of archaeologists, who did not necessarily measure every brick. Second, certain categories, such as mortar thickness and size of bricks in vaults, had to be omitted due to inconsistent or imprecise reporting of these attributes. Finally, coatings are commonly renewed several times a year. For Sudan, the measurements commonly pertain to the last occupation state of the building but this information is not always available for other regions.

4. Results

Hypothesis 1a suggests that little variation was to be found within one region but greater variation between regions. We measured this variation within brick size, firebrick size, mortar thickness, and brick

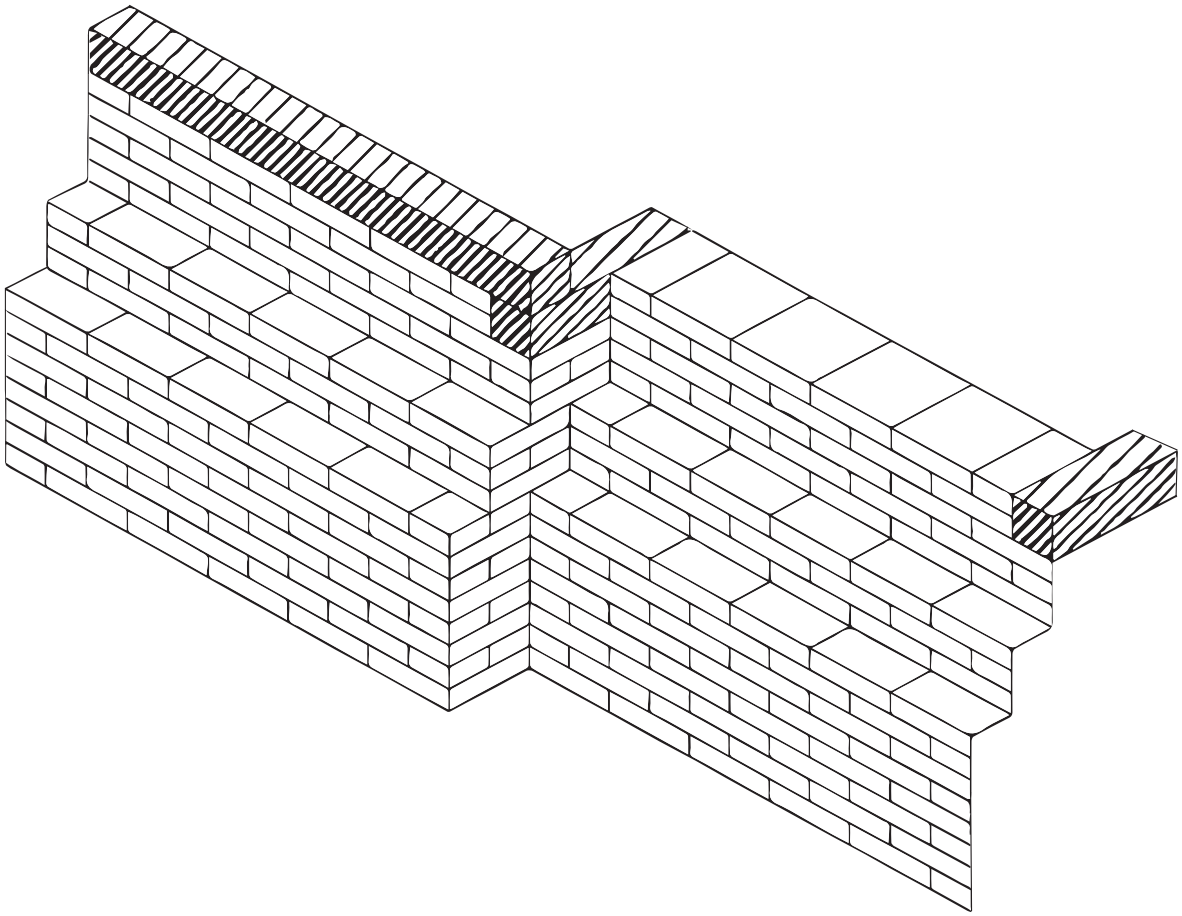

Fig. 7. Example of a brick-laying pattern of M 546 in Babylon (Near East), after Koldewey (1931, Fig. 5).

laying patterns for each building in each region.

Meroitic (Sudanese) palaces are characterized by high similarity, particularly in terms of brick sizes. There was only one size reported (although in some cases information was not available). Both mud brick and fired brick sizes were consistently the same in the archaeological record both within and between structures. The Egyptian structures only used mud bricks and no firebricks were observed. None of the reported mud brick sizes in Egypt was identical to the one consistently found in Sudan. Similarly, the Near East reported several sizes of mud bricks and firebricks but none of them overlapped with those in Egypt or Sudan.

Mortar thickness varied both within palaces and between palaces in Sudan. In Egypt and the Near East this thickness was either not reported or consistently the same for both regions.

Buildings in Egypt showed two brick laying techniques also prevalent in Sudan. Less common variations were specific to both regions. The brick laying techniques in the Near East were all different as they used square bricks that do not allow the same variations and, therefore, did not overlap with those in the other two regions.

Table 2 shows that the brick size is significantly different by region. This fits the prediction that this variation is regional. Mortar thickness variation overlaps between Egypt and the Near East, while brick laying techniques overlap between Sudan and Egypt. They point at possible points of CT between these regions.

Support for Hypothesis 1a comes from the finding that the size of the bricks differed between the regions. However, it does not explain why they would be standardized in size within Meroitic Kingdom palaces, but variable in size in Egypt and the Near East. This holds for both fired and mud bricks in the Near East, but only for mud bricks in Egypt. This variation was found between palaces and occasionally, i.e., only once in each region in the case of our sample, between structures within the palace. As detailed earlier, this absence of variation is likely explained, at least to some extent, by a lack of reporting on the part of archaeologists and/or the poor state of preservation of the remains.

The results of the statistical analysis for hypothesis 1b and 1c are summarized in Table 3. This table lists Cramer's V similarity coefficients for the three regions as well as the structures within each palace. It shows which item (column 1) is similar across regions or across structures. A value close to 1.000 suggests high variation while a value closer to 0.000 suggests high similarity. The outcome supports Hypothesis 1b, which predicts high variation between regions, but not between structures, for locally sourced materials exemplified by brick material, mortar type and coating type. Hypothesis 1c was also supported as coating layers and thickness had little to no variation between regions. This number is not zero as the absence of a reported value is counted as a variation and, in addition, palaces may also vary in the presence-absence of architectural structures. The resulting high similarity can be explained by the presence of prestige bias for the most visible aspects of the structure.

Hypothesis 1b predicts that prestige bias would likely influence the most visible elements of a palace structure, such as coating, more readily than techniques that are hidden within the structure, such as brick size. Indeed, only coating thickness and number of coating layers were found consistent across all three regions as is shown in Table 3.

Hypothesis 1c maintains that the ingredients of raw materials are locally sourced. The elements contained in (mud) bricks, mortar, and coating were reported in all instances and found with much variation in Egypt and the Near East but less so in the Meroitic Kingdom. Overlapping availability of material content was attested and variation was mainly found in the combination of ingredients for mortar and brick.

Table 1
Overview of selected monumental structures.

Sudan		Egypt		Near East	
B100	Hinkel and Sievertsen, 2002:71	Amheida, House B2	http://dlib.nyu.edu/awdl/isaw/amheida-ii-house-b2/	Abqac	Trumpelman, 1982:52–54
B1500	Roccati, 2004:384–387	Edfou Central house	Michałowski et al., 1950: pl. IV, V	Abu Habbah	De Meyer, 1980:43
B2400	Roccati, 2008:251–258	Edfou Northern house	Michałowski et al., 1950: pl. IV	Aq Tepe	Shakir, 1979:555
KAR 1000	Woolley, 1911:21–25	Karanis E102	Husselman, 1979:9, 33	Abu Ghab	Faraj, 1979:582
KAR 200	Woolley, 1911:28–31	Karnak House A	Lauffray, 1995:311–318	Abu Qubur	Gasche, 1991:12–16
M251–253	Hinkel and Sievertsen, 2002:99–100	Karnak House D	Lauffray, 1995:321–326	Babylon	Koldewey, 1932:59
M294–295	Hinkel and Sievertsen, 2002:110–118	Philadelphia House D6	Viereck and Zucker, 1926:4–6	Iresheideh	Muhsin, 1979:489
M750	Grzymski, 2008:46–50	Soknopaiou Nesos II-201	Boak, 1935:11	Khubari	Dawoud, 1979:598
M950	Hinkel and Sievertsen, 2002:131–132	Soknopaiou Nesos IV-401	Boak, 1935:17–20	Nuffar	Knudstad, 1968:97–100
M990	Hinkel and Sievertsen, 2002:132–133	Tebtynis 3200-I	Hadji-Minaglou, 2007:132–135	Qalat Shergat	Andrae, 1933:26–27
M995	Hinkel and Sievertsen, 2002:133–134	Tebtynis 7500	Gallazzi and Hadji-Minaglou, 2000:22	Sha'ir	Ali, 1979:551
M996	Hinkel and Sievertsen, 2002:136–137	Tebtynis 7600	Gallazzi and Hadji-Minaglou, 2000:22	Sinkara	Lecomte, 1989:94
M998	Hinkel and Sievertsen, 2002:138–140	Tebtynis, House 4200-II	Hadji-Minaglou, 2007:76	Suse	Ghirshman, 1954:13
MWS A	Maillot, 2013:249–256	Tell el Herr, Tower-House	Valbelle, 2007:42	Warka	Walker, 1981:94–95
WBN 100	Hinkel and Sievertsen, 2002:65–77	Tell el-Herr, House 8	Valbelle, 2007:137	Yorgan	Starr, 1939:29

Table 2
Number of variations: brick size, mortar thickness and brick laying.

Region	Sudan	Egypt	Near East	Overlap
Observations	120	120	120	
Mudbrick sizes (#)	2	18	13	0
Firebrick sizes (#)	2	1	7	0
Mortar thickness (#)	4	2	2	2
Brick laying (#)	5	4	3	2

This low similarity across regions is shown in Table 3. We found the same amount of variation for each region but with qualitative differences in the type of material, which is congruent with hypothesis 1c.

5. Discussion

Architecture is a complex cultural trait that lends itself to the analytical methods developed for CT theory. We analyzed a dataset that gives insight into horizontal transmission processes among three regions that are thought to have been connected in ancient times. The study lays the basis for future studies using a diachronic approach that could also include a phylogenetic analysis for architectural traits.

The transmission of architectural traits between Egypt and Sudan in Late Antiquity is often explained by the prominent role of Philae (Ahmed, El-Din, & Anderson, 2008: 40–46), an important pilgrimage center, that would have allowed Nubian (i.e., Meroitic) builders to familiarize themselves with the Egypto-Roman tradition. Indeed, the first contacts between Romans and Meroites are recorded on multilingual inscriptions at Philae by the first Prefect of Egypt, Cornelius Gallus. The Latin text underlines the fact that the Meroitic king was placed under Roman protection, and that a local governor was appointed to administrate the border. The Greek section of the text mentions the prefect as a friend of the Meroitic ruler (Török et al., 1996: 689). A few other occurrences clearly indicate contacts between Roman Egypt and Meroe describing religious visits to the temple (Török et al., 1996: 1000). These interactions, attested from the beginning of the Meroitic period onwards, may have inspired broader influences and exchanges of information. Our data show overlaps in monumental contexts, which have been attested before from a historical perspective. For instance, monumental Meroitic structures have been compared with traditional "peristyle" complexes from the Hellenistic period (Török, 1976: 71–103; Török, 2011: 133). This typological comparison was expanded to palaces, i.e., Wad Ben Naga 100 and Barkal 1500 (Hinkel and Sievertsen, 2002:70). It is suggested that these palaces resume the classical Hellenistic palatial model inherited from the Greek buildings located in the Egyptian settlements, such as in Alexandria, el-Mansha, Crocodilopolis, or Philadelphia. The wide variety of palatial plans of the Mediterranean basin shows that the solutions considered by the Meroites are mainly those passed through an Egyptian filter and adapted to local needs, given the consistency and regularity of the methods used.

The multifaceted aspect of a building includes both elements that are likely to be influenced by the environment and those that are cultural. The visibility of an edifice and the status associated with a palace suggests that prestige bias is a likely effect in the process of CT. Horizontal transmission of the two features that were most likely affected was complete and this may suggest that emblematic features of architecture undergo very high "realistic levels" of horizontal transmission as problematized by Greenhill et al. (2009:2302–2303).

The movement of workers across ancient borders could have assisted in the transmission of building techniques. However, the data presented in this study suggest that the extent of this influence in Sudan, Egypt, and the Near East is limited. Brick laying techniques overlapped only between Egypt and Sudan but not the Near East, while brick sizes were different in each region with variation specific to a structure rather than a region. This suggests that these elements of

Table 3
Similarity across regions.

	Region			Structure		
	Cramer's V	χ^2 (*df*)	p	Cramer's V	χ^2 (*df*)	p
Brick material	0.86	537.89 (24)	< 0.001	0.22	116.53 (84)	0.011
Mortar type	0.90	583.41 (28)	< 0.001	0.22	121.10 (98)	0.057
Coating type	0.87	548.34 (16)	< 0.001	0.18	83.48 (56)	0.010
Coating thickness	0.26	24.91 (2)	< 0.001	0.43	65.77 (7)	< 0.001
Coating layers	0.26	24.91 (2)	< 0.001	0.43	65.77 (7)	< 0.001

palaces are more suitable for an analysis of vertical transmission.

While the size of the bricks differed between the regions as expected, there is no explanation as to why they were so standardized in the Meroitic Kingdom, both within and between structures, but varied substantially elsewhere. This suggests that bricks were produced on site using different molds for new building projects as opposed to a nationwide standard mold for brick production in the Meroitic Kingdom. In other words, mold size was not part of CT in the region, but rather, a technique particular to a building site. Although little variation was found due to the coordinated efforts needed in one structure, brick sizes, even though highly standardized in the Meroitic Kingdom, fluctuate within the palaces of both the Near East and Egypt and sometimes even within the walls and structures of a single palace.

A strong prestige bias is expected where the overall design and size of the building is concerned. These aspects were not included in our comparison. There is substantial evidence, for instance, that the Meroites, who built an array of structures in Sudan, used the shape of an elite-type Egyptian pyramid for their own pyramid structures, also using similar shapes of temple features. In the case of palaces, and probably for several other structures, the overall outside shape has less iconicity. Also, the particular details of the outside decorations of a palace are often lost due to attrition and degradation of a building over time. However, the coating thickness and number of coating layers are an important part of its overall appearance. Even if the bricks are of a different make and model, and placed using a different system, the coating will largely obfuscate such differences. This final outer layer is strikingly similar across all three regions.

The results further confirm that environmental factors influence local building materials. The ingredients of mortar, coating, and brick were different for each region. The content of mud bricks was diverse in the Near East but hardly so in Egypt. Mortar and coating content shows much variation outside the Meroitic Kingdom and although ingredients similar to the Meroitic Kingdom are also found, the common constituent elements are different. This pattern suggests that ingredients were locally sourced and materials locally produced. Following our prediction, materials diversified over space and were most different between the regions.

Finally, there is a remarkable lack of variation within buildings and between buildings of one region during the studied time period. Standardization was most pronounced in the Meroitic Kingdom, suggesting that regional or cultural coherence winnows variation in the case of architecture.

In sum, predictions drawn from CT theory about the horizontal transmission of architectural traits conform largely with data from Sudan, Egypt, and the Near East. This outcome lays the foundation for future studies that can focus on the role of vertical transmission within particular features that vary significantly between regions but are more conservative within a region. As well, the study highlights the role of prestige bias in structuring more visible components of architecture, and the role of the environment in structuring less visible components. Additional studies of different regions or with a diachronic perspective may show if hypotheses about the cultural transmission of architecture can be generalized across time and space.

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