Scanning the face of the McManus tsantsa

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Abstract

In continuation with the journal, ‘Facial Analysis of Tsantsa’ (Houlton, 2011), the McManus tsantsa was reconstructed in 3D form. This is the first time a tsantsa face has been reconstructed; no previous analyses exist. To predict how the tsantsa subject may have looked pre-mortem, a 3D facial approximation was attempted; the limitations being that the victim’s skull was unavailable for analysis. The McManus tsantsa was scanned using a FastSCAN™ Polhemus Scorpion™ handheld laser scanner and imported into 3D modelling software (FreeForm Modelling Plus™). The tsantsa scan was constructed utilizing craniofacial measurements, obtained from the McManus tsantsa and superimposed subject photographs. A template cranium was scanned and manipulated in FreeForm™ to conform to data based on average Peruvian craniofacial measurements. A template mandible was developed using Sassouni Analysis. The complete Peruvian template skull then provided a hypothetical scaffold which guided the tsantsa reconstruction; final texturing and rendering was made using Autodesk® Maya® 2010. The end results provided a demonstration of the hair and adornments common amongst Shuar tribesmen at the time the head was collected. The reconstruction could not be verified due to the absence of ante-mortem photographs.

Introduction

This is the first time a tsantsa face has ever been reconstructed; no previous analyses exist. There is however case documentation of a severely disfigured face, which was rebuilt by a forensic anthropologist, where only small fragments of the occipital bone and a few teeth from the original skull were present (Quatrehomme et al, 1996). A template skull was utilised to provide a basic structure for tissue and shreds of skin to be assembled. The cast of the face was compared with an antemortem photograph of the subject and the reconstruction was deemed successful, given the condition of the face. The McManus tsantsa, ‘disfigured’ in a different manner, required similar scaffolding to remodel the face to be consistent with human proportions.

Forensic facial reconstruction uses the skull form to determine the shape and size of the soft tissues (mostly muscles) that underlie the face. The skull is removed during the head shrinking process – which is why the McManus tsantsa had no skull on which to base a reconstruction.

From the pig head trial (Houlton, 2011), it was determined that cartilaginous areas shrink at a slower rate than the rest of the skin, forcing the nose into a pronounced and upturned position, which emphasises the nostrils.

To best present how the tsantsa subject might have appeared in life, it was recreated as a young male, age 20-30, from the Shuar tribe (Houlton, 2011).
Method

Surface scanning of the McManus tsantsa:

A 3D model of the McManus tsantsa was created with a FastSCAN™ Scorpion laser surface scanner.

Scanning was performed in dim light with the tsantsa securely positioned. The transmitter was positioned close to the tsantsa. The FastSCAN™ software filters each scan. Profile smoothing was set to “low” (options being low, medium or high), to avoid loss of detail. Wand sensitivity was set at 2 (from a scale of 1 (minimum sensitivity) to 6 (maximum sensitivity), to preserve maximum obtainable detail without unwanted artefacts (Polhemus, 2007).

The tsantsa’s dark skin and tight features required careful scanning. The hair was problematic, as the scanner light beam reflects off hair, causing distortion of image data. Only the skin surface of the tsantsa could be scanned; eyebrows and feather ear ornaments were excluded.
Scanning a 3D object requires multiple sweeps. These sweeps were “Registered” while processing, and amended small errors in scan sweep alignment (Polhemus, 2007). A “Basic Surface” was generated to merge sweeps smoothly. Parameters controlling this function are available within “Generate Surface”. “Smoothing” option controls the extent to which each individual sweep ‘stitches’ one into another, (set at 1.0). The “Decimation” value, which affects the triangulation detail of the scan and subsequent file size, was set to 0.5. Completed scans were exported as .stl (stereolithography) files, which opens in Freeform Modelling Plus™ software (SensAble Technologies™, 2002), a 3D touch-enabled system for fast 3D modelling (Zollikofer, et al., 1998; Subke, 2005).

Reconstructing the scan in Freeform Modelling Plus™:

The .stl files were imported into FreeForm Modelling Plus™ version 9.0 (SensAble Technologies™). This 3D software integrates a PHANTOM™ desktop arm and a haptic force feedback device that provides the user with a sense of touch (SensAble Technologies™, 2002).

When importing files from FastSCAN™ to Freeform™, an option is available to “fill holes” in the 3D image, which preserves morphological detail.

The imported scan is as displayed in Fig. 2 (see next page).

A number of unwanted artefacts were visible in the McManus tsantsa scan. This was cleaned using the “Carve with Scraper” and “Cut” tool, which cleaned the scan while avoiding cutting away needed detail. Residual roughness was cleared with the “Smooth” tool.

Those features which scanned poorly, were rebuilt, i.e. parts of the eyelids, top of the nose, part of the lips, neck and scalp. Front, side and bottom profile photographs of the tsantsa, were used to superimpose with the scan, as a visual aid, or reference, for remodelling the head. On a separate layer, head and face features were outlined - hard lines drawn to indicate clearly defined features, dotted lines for less distinct features. With each photograph, a separate photograph, outline image and combined photograph and outline were saved individually as compressed .jpg documents.

The prepared Photoshop® images were imported into planes on FreeForm™, and positioned to overlay the McManus tsantsa scan. Feature outlines on the tsantsa were aligned with the ‘best fit’ of the outlines on the imported images. Remodelling was achieved by using the “Add Clay” feature, with the plane outlines as guides.

To check the accuracy of the rebuilt scan, the measurements collected from the McManus tsantsa (Houlton, 2011), were compared with those from the scan model, with the “Ruler” tool. Small adjustments were performed in the scalp region using the “Tug” tool.
Fig. 2: Front [top] and side [bottom] profile of the McManus tsantsa scans, imported from FastSCAN™ into FreeForm Modelling Plus™, displaying artefacts that require ‘cleaning’.
Fig. 3: Example of planes being used to reconstruct the McManus tsantsa face


(In FreeForm™).
Fig 4: Side profile of the McManus tsantsa. Top, Side profile photograph with red outline highlighting contours in Photoshop® CS3.

Bottom, Shaded in green the original scan model. Shaded in beige is the remodelled head with the red outline used as a guide in FreeForm™.
Results

Fig. 5: Front and side profile of the reconstructed McManus tsantsa scan in Freeform™.
Conclusion
Laser scanning was limited to external surface scanning. Dark, or complex surfaces were difficult to scan well. Ideally, CT (computerised tomography) scanning would have provided considerably more skin surface detail.

Modifications to the scan were successful, as the scan appeared to match both the photographs and the measurements.

The tsantsa scan was now ready for facial reconstruction.

Construction of a template skull

Introduction
Laser surface scanning and 3D computer software was used to create a template skull. This template provided a support for resizing, scaling and moulding the tsantsa scan. The template followed guidelines based on a mongoloid ancestry. The appropriate ancestry group for the McManus tsantsa’s origin.

The cranium
A normal Peruvian cranium, appropriate geographically to the Shuar tribe, was selected.

The skull was scanned using the FastSCAN™ laser scanner. The file was saved as an .stl, for import into FreeForm Modelling Plus™ (SensAble technologies, 2002).

Within FreeForm™, the scan was redesignated as a FreeForm™.cly file. At this stage, the cranium was unique to the individual. 55 male crania measurements from Howell (1989), (Male Peruvian) provided mean measurements for an ‘average’ Peruvian skull.

N.B. Cranial data was only available for Peruvian crania, not Ecuadorian, but the cranial size and shape was not expected to vary dramatically, being from a similar geographic region and similar genetic variation.

Howells’ (1989) data was implemented to modify the scanned cranium in FreeForm™. Measurements specified for the left side of the cranium were replicated for the right side, as no right side data was available. The “Ruler” tool and the “Tug” tool measured and manipulated the structure.

The mandible
The mean data available on Peruvian skulls was confined to the cranium; the mandible was therefore estimated using a method incorporating roentgenographic cephalometry. This involves the assessment of lateral and frontal x-ray films of the head to provide sizes and proportions in three dimensions. Using this data, Sassouni Analysis was implemented to construct the dental arches and mandible (Sassouni, 1957).

Geometric, proportional techniques produce individual, analytic results appropriate for mandible estimation (Sassouni, 1957).

In order to perform Sassouni Analysis, a cross-sectional view of the cranium is required. This is because Sassouni Analysis depends on both external and internal cranial features, to draw the essential planes and axes, for mandible estimation. The template cranium in FreeForm™ was produced using the FastSCAN™ laser scanner, which is only capable of surface, not cross-sectional, scanning. A lateral projection of a skull radiograph (2SkullRad.png, see Fig. 6, [Left]) was imported into FreeForm™ as a new plane. This was repositioned in front of the cranium in a profile view. The scale of the plane was downsized to make a ‘best fit’ between the outline of the radiograph and the outline of the template cranium (see. Fig. 6, [Right]).
Another plane was created and positioned in front of the skull radiograph. On this plane a set of lines and axes were drawn establishing the visible set of norms that exist on the cranium using Sassouni Analysis.

A template mandible was scanned and imported into FreeForm™ using the same methods as per the cranium, and modified using the “Tug” tool to fit the cranium within estimated dimensions.

Discussion

Using mean cranial data for Peruvian skulls produced an average cranium. This avoided the template cranium from being biased toward the particular individual from which the original scan was made.

Sassouni Analysis (1957) is focussed upon identified craniofacial norms, which can be interpreted and implemented during mandible reconstruction. It is a promising method for mandible reconstruction because of its simplicity and proposed accuracy, but Sassouni (1957) states his work can only be considered a preliminary report. The method presented in Sassouni’s research (1957) does not state the ancestry groups to which it has been tested against, and therefore may not be appropriate for use with all ancestry groups. The reliability of the method also relies on craniofacial norms. This is limiting, because some individuals may be morphologically different from a norm.

Conclusion

The production of this template skull depends upon averages and craniofacial norms; it does not necessarily represent the skull shape that the McManus tsantsa once had. It must therefore be treated as a hypothetical anatomical reference during the facial reconstruction, to avoid exaggerations or distorted proportions in the facial morphology.
Facial reconstruction of the McManus tsantsa

The scan of the McManus tsantsa was positioned and scaled to fit with the template skull (see Fig. 9). Craniofacial landmarks were used to align the tsantsa with the template skull. These included the vertex, eurion, maler, nasion, gnathion and the dental arc. The tsantsa scan was made translucent to visually optimise its placement over the template skull.

The tsantsa scan model was temporarily made invisible to focus attention on the template skull. To ensure that the skin surface of the head, at particularly bony landmarks, were at an appropriate thickness for a Mongoloid South American, a separate offset layer was produced from the template skull (see Fig. 10). Data held on mean male tissue depth thicknesses amongst a Mongoloid group (Korean), taken from Wilkinson (2004), was used. The forehead tissue depth (4.5 mm) was used as it is least affected by muscle and fat layers.

With the offset layer as a reference, the tsantsa scan model shape was amended using the “Tug” tool. The superior and posterior of the head were structures, which were distorted, due to the lack of a cranium as a model, and were therefore adjusted to adopt the shape of the offset cranium.

Reconstructing the face required more consideration, as facial features were distorted in an exaggerated dolichocephalic shape. The width of the cheeks in the tsantsa scan, were expanded over the template skull, which allowed for the thickness of the cheek muscles (i.e. masseter, buccinator and risorius,) and the parotid gland.

The exaggerated prognathism of the mouth was reduced, allowing space for the orbicularis oris. Some prognathism was maintained, as it appeared greater than in other studied tsantsa.

Although no teeth were present in the scanned template cranium, the reference of the first premolar-canine junction, from the alveolar process, suggested the placement of the chelion points (corners of the mouth). The tsantsa mouth was disproportionately narrow; therefore the corners were extended to meet these landmarks.

As a result of the processes in head shrinking, the facial proportions of non-cartilaginous areas of the face, in relation to each other, are kept similar; it is only their scale that changes. The lip thickness of the scaled-up tsantsa did not therefore require much change. The lips appeared to fit in scale with other craniofacial details and the template skull. The lips were however distorted into an exaggerated protrusion, therefore following the detail in the tsantsa scan and photograph, the lips were refined using the “Tug” tool.

The nose was most dramatically affected. To reconstruct it, photographs of existing Shuar tribesmen were used as reference (see Fig. 11).

The nose of the tsantsa appeared rounded, much like those of the Shuar. A pre-formed model of a nose, that was similar in structure, was imported to replace the distorted tsantsa nose. It was positioned to fit proportionately over the existing tsantsa scan nose. From photographs of the Shuar, it appears that their noses often lie on a horizontal plane (some are up-turned). The McManus tsantsa nose, being more upturned in comparison to other studied tsantsa, was reconstructed in such a way that it was upturned rather than horizontal.

The reconstruction required the eyes to be open, as in life. To reconstruct the eyes, two spheres were made using the “Add Clay” tool (25mm diameter), and positioned in each socket as defined by the orbital bones using the Manchester Method of forensic facial reconstruction (Wilkinson, 2004).
**Fig. 8:** Reconstructed scan of the McManus tsantsa beside the template skull in FreeForm™.

**Fig. 9:** Front and side profiles of the McManus tsantsa scan overlaying the template skull, as a best fit in FreeForm™.
To model the eyelids, a pre-formed orbicularis oculi muscle was imported. This was adapted to fit over the eye and template cranium following the Manchester Method of forensic facial reconstruction. The angles of the eyelids were formed to follow the angle set by the eyelids in the tsantsa scan, which were horizontal to slightly up-turned outwards.

To model the ears, a pre-formed left and right ear model were imported and positioned using the orientation of the external auditory meatus. The length of the ear is equal to the length of the nasal profile. The ear on the McManus tsantsa was angled slightly posteriorly; the lobes were non-adherent, this was replicated on the reconstruction. Due to shrinking, the projection of the ears could not be estimated - so an average projection was used. Tsantsa ears appear to be positioned close to the head. Shuar ears do not appear prominent.

*Fig. 10: Offset cranium and mandible piece in FreeForm™.*
Fig. 11. Examples of Shuar tribesmen (Korsten, 1935 and Stirling, 1939).
Fig. 12: The positioning of the template skull in relation to the reconstructed tsantsa face in FreeForm™.

A template neck and torso were imported from an existing database consisting of pre-modelled anatomical structures (see Fig. 13). These were scaled, remodelled and manoeuvred to fit the reconstructed head.

When all structures were in place, they were merged into one model (except for the eyes and template skull). Creases found in the facial structure of the tsantsa were marginally smoothed to reduce their exaggerated appearance. These creases were caused by absent facial bones causing the facial structure to fold. Using the “Tug” tool, creases were orientated to better follow natural contours of the face where bone would have been present. These were minor changes.

Following Shuar tribe fashion, ear tubes (or “Jarusa”), were modelled and positioned through the lobes. In Autodesk® Maya® 2010 the reconstruction was textured and rendered to display how the tsantsa may have looked as a living Shuar tribesman, considering it was reputed to be a war trophy, most likely intertribal (Stirling, 1938; Jamieson, 2010), from the head-hunters of the Amazon (McManus Museum) (see Fig. 14).
Results

Fig. 13: The completed facial reconstruction of the McManus tsantsa in FreeForm™.
Fig. 14: Decorated tsantsa reconstruction, representing Shuar fashion, in Autodesk® Maya®.
Discussion

The reconstruction of the McManus tsantsa incorporated as much scientifically based information as possible. The facial proportions were produced by analysing and applying knowledge gained from studying the effects of head shrinking on the soft tissues of pig heads, using a template skull for a basic reference and fundamentals of facial anthropology. During the reconstruction the tissue depth data was used as a mean sample from an existing Mongoloid group (Korean) available (Wilkinson, 2004). It is now known that tissue depths specific to South-Western Indians were available from Rhine (1983), which would have been more appropriate. The forehead measurement, in comparison with the 4.5mm Korean tissue depth data, provided a tissue depth of 5mm - a 0.5mm difference. This is not a major issue, as it affected the scale of the head, not the appearance of the face shape. The offset skull piece was only used as reference for skin placement on bony regions of the head and face.

While inflating the McManus tsantsa scan, care was taken to consider how the face would be affected with the added structure of muscle, fat and bone. The template skull, along with knowledge gained from some practise in forensic facial reconstruction, was used as references to how these underlying structures may dictate the external facial appearance. Minimal remodelling of the face was performed, to maintain as much of the individual’s facial characteristics as possible. The nose however, required more adjustment as the effect of shrinking dramatically distorted this feature.

Existing photographs of the Shuar (see Fig. 11), were referred to throughout the reconstruction as a guide to their general morphological appearance.

There was some reliance on personal judgement, which may have resulted in a more idealised result - the reconstruction depicts a fit, healthy, strong warrior, which may have been far from the reality.

The addition of texture and colour effectively brought the reconstruction to life, and the application of jewellery and combed hairstyle, was a fair representation of Shuar fashion at the time this individual lived.

Overall, the results were satisfactory.

Conclusion

The reconstructed image of the tsantsa reasonably reproduced how the tsantsa may have appeared in life. The reconstruction depended heavily on visual interpretation and morphological averages set by a template skull. Accurate facial proportions are lost when a cranium is no longer present to act as a structural scaffold. The head, when shrunk, does not maintain the original proportions, as evidence in the pig shrinking tests. The operator, as well as the techniques chosen, also influences the shrinking. Certain features can therefore, be exaggerated relative to others. This makes the level of achievable accuracy limited. Finally, the reconstruction cannot be tested for accuracy because there are no existing antemortem images of the McManus tsantsa.

References


Houlton, T (2011), Facial Analysis of a Tsantsa (shrunken head).


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