THE SENSORY ARCHAEOLOGY OF TEXTILES

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Abstract

Textiles are sensuous; we respond to them through touch, vision and smell, movement, sound and temperature. Through sensations, textiles embody emotions of identity, and define hierarchies of power and value. Yet through the taphonomy of decay, ancient textiles are frequently devoid of their original sensory properties, they come to us as faded, fragile, dirty rags. A sensory archaeology of textiles, therefore, requires a suite of methods to reveal these sensations and a contextual analysis to interpret them within their chronological and regional archaeologies. In raising to this challenge, this chapter proposes for the first time a sensory archaeology of textiles. Through innovative case studies, the author invites the reader to recognise the implications of a sensory archaeology of textiles, and to consider the consequences for their own research fields.

Introduction

Textiles are decidedly sensory materials. Textiles move, they can be textured and lustrous, they retain scents and colourful dyes (see Schneider and Weiner, 1989, pp.1–2). In their sensory delights, textiles can enchant and create splendour, making some textiles as desirable as gold. In clothing, textiles transform the body, the sense of self and others (Eicher and Lee Evenson, 2015, p.33). This transformation is visual, ergonomic and protective (Watkins, 1984). The production of textiles, like other crafts, is rhythmic, haptic and visual (Hurcombe, 2007, p.539). More prosaically, textiles fade and tear, they collect stains, smells and dirt. In production, the necessary repetitive and laborious tasks can be arduous and painful. Textiles form the basis of clothing, covers and containers and in this they are closely related to other cloth-type materials of leather, furs and interlaced fabrics made by techniques other than weaving (Harris, 2008, pp.225–227). Because textiles wrap, reveal, highlight and veil (Douny and Harris, 2014), they are also sensory chameleons, significantly changing the perception of those bodies, places and objects that they cover and contain. People perceive and know textiles through their bodily senses; through the way they feel, appear, smell and move. This process is active and perpetual, yet largely unconscious (Gosden, 2001, p. 163).

To take an everyday example, when we buy a raincoat, we inspect its colour, feel the cloth, and try it on, we may seek information on its resistance to water permeability. We do this because our choice of raincoat effects our life. If it keeps us dry and warm when it is cold and wet, we can occupy the outdoors in a way that we could not without it. If it does not fit, it could affect how we behave, move or see. We may be self-conscious if our raincoat starts to smell or if it rustles in the cinema. Our appearance in our coat affects how we relate to the people around us, if we have what is perceived to be the ‘right’ style, brand or colour, this may enhance others' perception of us. In this way, the raincoat is an extension of ourselves, and it belongs to our particular sensory environment. It is distinct from a raincoat of 100 years ago. Often, we are so accustomed to these sensory judgments that we barely notice them. If this is a sensory experience of cloth, what then is a sensory archaeology of cloth, what are its methods and what can it achieve?

As with our raincoat, the perception of textiles is cultural. People are socialised into the senses. In this way, perception is prejudiced, as from a young age we are taught to pay attention to certain senses and dull others (Classen, 1993, pp.46–47). We learn which textiles to pay attention to, and which ones to dismiss. Through this learning, people are educated into the sensory orders that perpetuate the norms or subgroups of society. In archaeology these norms (or otherwise) are detected through the spatial distribution and chronological sequence of textile types, shifts in fibre resources, and fashions in colour, pattern and texture. For archaeologists, sensory experience is in the active engagement between people and things embedded in situations, events and relationships, and so belong to a particular time and place (following Gosden, 2001, p.163; Skeates, 2010, p.2; Hamilakis, 2013, p.8; 2013; Day, 2013). A sensory approach to archaeological materials, therefore, is an invitation to re-examine research questions and methodologies (Hamilakis, 2013, p.8). This requires an explicit redirection of analytical and interpretation strategies. For this reason, a sensory archaeology of textiles is both an analysis of the multiple sensations of ancient textiles (the artefact of study), and an interpretative framework that seeks to understand people's perceptions of such textiles in their sensory environment (the contextual interpretation). It has relevance to how textiles are contextualised in the past, and how they are analysed and presented in the present.

A Dulling of the Senses: A Very Short History of Textile Research

> 'Material culture exists in 3D full colour perceived by all the senses working together, but it is conveyed via word and limited, 2D, mostly black and white illustrations. Many specialists have a clear sense of their own material and bring their sensory perception to its study, but this is not overtly discussed'
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> (Hurcombe, 2007, p.541).

Archaeological textiles, when preserved at all, are usually fragmentary, decayed, discoloured and dirty. They are physically and chemically transformed and no longer retain their original properties (Wild, 1988, pp.7–12). For specialists it is essential to be able to analyse, record and compare preserved textiles through objective scientific analysis. Weave structures are classified into types. Attributes of cloth are transformed into statistical tables. Traces of pigments and dyes are recognised according to elements in the periodic table. Raw materials from plants and animals are given Latin names. Unwittingly, for many years these practices of classification and publication have estranged readers from the sensory potential of textiles. Three-dimensional fabrics are reproduced in two dimensional black and white photographs, schematic diagrams and micrographs. To the uninitiated, terms such as S2z, tabby, *Isatis tinctoria L.* placed alongside photographs of what look like little more than rags are alienating and far removed from the sensory world of cloth. As a result, there has been a sensory disconnect between the archaeological textile artefact and the sensory materials that existed in the past.

From the late 1960s onwards textile specialists have established fabric and yarn classification schemes (Emery, 1966; Seiler-Baldinger, 1994), standardised measurements (Walton and Eastwood, 1988) and used microscopy to identify fibres (Catling and Grayson, 1982; Janaway, 1983; Ryder and Gabra-Sanders, 1985). This has provided a basis to identify raw materials, technology and the evolution of textile production (Wild, et al., 2014; Jenkins, 2003; Bender Jørgensen, 1992; Barber, 1991). The practice of finds analysis is itself sensory (Hurcombe, 2007, p.541); fragile textiles found on excavations and stored in museum collections have their own code of conduct around handling, packing and holding (Gillis and Nosch 2007, pp.6–11). However, even before publication, textile research methods actively work against engaging seriously with human sensation. Strict adherence to scientific rigour and objective reason, while playing a valuable role in forwarding technical knowledge of textiles, implicitly blocks other approaches. The analysis of archaeological textiles using these methods and their subsequent development remains foundational to understanding ancient textiles. It also established the academic culture of textile analysis and interpretation; prescribing what to pay attention to, and what to dismiss.

Within this framework the textile archaeology that developed prior to the 2000s emphasised the technology, spatial distribution and diachronic development of textiles. There are hints of the sensory qualities of textiles and the sensations of production. *The Cambridge History of Western Textiles* (Jenkins, 2003) is a major synthesis of research written by a generation of scholars who started researching archaeological textiles in the 1970s and 1980s. In the introduction, the focus is on technologies of production, yet among these weave structure is recognised as texture, and raw materials and techniques of dyeing are grouped by the colours they produce (Wild and Walton Rogers, 2003, pp.20–28). In later chapters these themes are repeated. Mesolithic weave structures from Tybrind Vig, Denmark (c. 4200 BC) classified as knotless netting and couched button hole stitch, are compared to ‘coarse knitting’, providing a reflexive marker of sensory materials (Bender Jørgensen, 2003, p.54). Across Iraq, Iran and Egypt (AD 600–1000), gold thread embroidery is noted for its glitter and iridescence; and cloth in general is noted as for its visual decoration (Vogelsang-Eastwood, 2003, pp.158, 164). There are glimpses of production as a sensory experience. From text, we discover the cramped working position of early New Kingdom mat weavers in Egypt, ‘His knees are drawn up to his belly, he cannot breathe the open air’ (Papyrus Sallier II 7:24, in Allgrove-McDowell, 2003, p.34). From this perspective, the authors hint at texture, colour, shine and posture.

While it is not possible here to present the breadth of research over several decades, overall textile researchers writing in the 1990s and before were willing to interpret sensory aspects of the archaeological cloth they investigated, yet adhered to methods and research traditions that prioritised analysis of raw materials, manufacture, distribution, evolution and economy. It is important to remember that, prior to the turn of the millennium, textile research was fighting to be taken seriously as a research field. It is probable that this had the effect of channelling research into conservative forms of analysis, reminiscent of Hawkes’ ladder of inference (Hawkes 1954, pp.161-162). Writing at the crux of a generational shift, Irene Good recognised the achievements of this generation of textile scholars, while seeing the need to address new questions: ‘These cumulative data we now have at our disposal are amply suited for a new generation of comparative studies and syntheses for addressing some basic anthropological questions’ (Good, 2001, p.219). Good was looking into a future that held the ontological turn, and a substantive shift across the sciences and humanities that brought a reengagement with materials and the senses (see for example Howes, 2006, pp.114–115; Hurcombe, 2007).What exists now are a number of innovative methodological and interpretative developments in textile archaeology that centre on people and materials. Still in an early stage of development, these methodological and interpretative advances are dispersed throughout the literature. For the first time, this chapter seeks to bring sensory textile archaeology into a cohesive body of approaches.

The Senses: An Overview

Sensations are things we hear, feel, see, smell and taste; broadly all those things we perceive through our bodily senses (O'Callaghan and Nudds, 2009, p.26). The western sensory tradition separates out the five senses of sight, hearing, odour, taste and touch. In other sensory traditions, there is a broader spectrum of sensory modalities, including perceptions of movement, balance and emotions (Skeates, 2010, p.8; Edwards, et al., 2006, pp.3–8). In the scientific literature sensations are described according to properties. For example, of visual senses, properties include colour, texture, brightness, size and motion (Frisby and Stone, 2010, pp.255–279). Tactile properties include sensations of body movement and position (proprioception, kinaesthesia), pressure, temperature, pain (cutaneaous), balance (vestibular) and mechanical force feedback (Fulkerson, 2014; Paterson, 2013, p.ix). In the auditory sphere properties embrace pitch, timbre, loudness, duration and location (O'Callaghan and Nudds, 2009). Odour properties describe strength, differentiation and the feeling which is the state of association between smell and experience (odour memory) (Engen, 1982). While each sense has its own distinct role, there is also interconnection between sensory modalities (Day, 2013, p.11; Edwards, et al., 2006, p.8). For example, visual analysis is often connected to touch experience. Indeed visual perception is the basis for estimating a wide range of sensory, technological and material information (Fleming, 2017). Similarly, sensations are connected to emotions of fear, awe and desire (Edwards, et al., 2006, p.8).

When researching textiles, sense properties are an essential starting point in working with complex source material, where—due to taphonomy and temporal distance—recognition of sense properties themselves are problematic. There are a range of methods to investigate sensory modalities of archaeological textiles (Table 1); these are elaborated on in the section below. Investigating sense properties broadens our perspective of the potential perception and effects of cloth. The weakness of a sense properties approach is that an object can become ascribed a fixed list of attributes without considering contextual perceptions and conditions. Here it is significant to recognise that sensations can also be conceived as events, which occur where 'objects and bodies interact with the surrounding medium' (e.g. of sound—O'Callaghan, 2009, p.48). The sensory events perspective draws attention to the contextual relationship between the object, the sensing body, and the medium of air, weather, presence of light, etc. For archaeologists an events perspective recognises that sensations are contextual because perceptions change across time and place, according to situations and social matrices.

Sensory modality	**Methods of analysis for archaeological textiles**
Visual (sight)	Observation of preserved colour, chemical analysis of dye substances, dye and mordant experiments, experience experiments,

	scientific literature on colour and pattern theories. Fibre, yarn and weave properties for colour, structure and texture. Effects of processing, finishing, washing and exposure to light on colour, brightness, texture, lustre, density. Visual grouping and calculation of cover factor for density, thickness and transparency.
Haptic (touch)	Fibre and fabric properties, fibre processing and wool quality analysis, clothing styles and comfort to investigate friction, temperature, mobility, insulation and texture. Tacit knowledge of materials gained from industry or craft professionals. Mechanical and physical testing of fibres, yarns and fabrics for strength, durability, weight, pull, strength, drapeand drag. Calculation of cover factor for density, thickness and resistance.
Auditory (sound)	Recording or classification of textiles related to sounds through archaeological experience experiments, reconstruction and replication. Reflexive and tacit knowledge. Analysis of textual sources (relevant for all sensations).
Olfactory (odour)	Description and classification of textiles and their related odours through archaeological experience experiments, reconstructions, reflexive knowledge. Odour characterisation of chemical signatures of fibres, dyes and other substances within or applied to cloth. Analysis of textual sources. Contextual analysis of associated odours, *Chaîne opératoire* or biography of objects to understand changes in odour during processing and according to use over time (relevant for all sensations).

Table 1. Methods available to archaeologists to investigate the sensations of textiles.

Sense Properties of Archaeological Textiles

Textiles are complex materials: to understand the appearance, feel, move, smell or sound of archaeological textile requires a suite of specialists and analytical methods. This section reviews current practice and innovative methods to investigate the sense properties of archaeological textiles. It is organised according to the major research methods used by archaeologists to investigate textiles: macroscopic, microscopic and scientific analysis, reconstruction and experimental archaeology. Examples review the range and potential of recent approaches to sensory textiles; the period and geography reflects my own research interests.

Macroscopic

Macroscopic analysis involves observation by the naked eye which may be augmented by low magnification microscopy (e.g. hand lens at x10). In textile research, macroscopic analysis follows an objective documentation system including observations on preserved colour, classification of weave and yarn structure, measure of thread count, spin direction, and the presence of wear and decoration (Walton and Eastwood, 1988, pp.3–17). In Early Iron Age Europe, for example, weavers used a rich repertoire of techniques to create colourful, lustrous and textured textiles. For example, a man’s semi-circular mantle from Tomb 89, Lippi, Verucchio, Italy, 725–650 BC was enhanced using an array of visual techniques (Stauffer, 2012, pp.244–245), many of which are recognised by macroscopic analysis. In this way, the identification of the twill weave and the patterned tablet woven borders provide information on the mantle's visual appearance and texture (Ræder Knudsen, 2012, pp.256–257). Thread count together with yarn diameter provide a relative scale of fabric fineness. Hence, the thread count of the mantle (12-14 per cm) contrasts to a second finer mantle (22–26 per cm) from the same tomb (Stauffer, et al., 2002, p.216). The spin direction of the warp and weft yarns were alternated in groups of six to ten z and s spun threads (Stauffer, 2012, pp.244–245). This is referred to as a spin pattern or shadow pattern, because the alternative spin direction effects the light reflection on threads. On this mantle it creates a lustrous, checked sheen. The dimension and truncated semi-circular shape of the mantle dimensions (at least 257x88cm) provide information on the size, drape and shape of the garment (Stauffer, et al., 2002, p.196). Consequently, the macroscopic analysis provides information on the visual texture, size, shape, orientation and lustre of this Early Iron Age textile garment.

A shortcoming of the standard macroscopic approach is that textiles documented with the same weave classification and technical characteristics often appear different from one another. This led trained spinner and weaver, Lena Hammarlund, to create a system of visual grouping of archaeological textiles (Hammarlund, 2004; 2005). Visual groups are founded in a comprehensive, verbal description the textile's appearance (Hammarlund 2013, 179). Grouping in this way, makes it possible to separate textiles with very similar technical attributes, but which have distinctive visual characteristics. At the Roman site of Mons Claudianus in Egypt this allowed the technically similar tabby (balanced plain weave) textiles to be separated visually into 'ribbed tabby', 'crowsfoot tabby' or 'flat tabby' (Hammarlund, 2005, p.17).

Underlying the concept of visual grouping is "The Pentagon", a simplified model of interrelated factors defining the relationship between the fabric construction and fabric appearance. The Pentagon is a five-way correlation of yarn properties (fibre fineness, crimp, absorbency; thread twist and diameter), binding (the system of interlacing), weaving (the role of the loom and weaver), finishing (processes after removal from the loom), and thread count (threads characteristics in warp and weft) (Hammarlund, 2013, p.179; 2005, pp.15-16) (Figure 1). Visual grouping places analysis back into the human sphere of integrated sensation and perception. It is rooted in a system that recognises that the final appearance of a textile is a sum of many stages in its construction which is based in the craftpersons' knowledge, skill, choice of materials and production techniques.

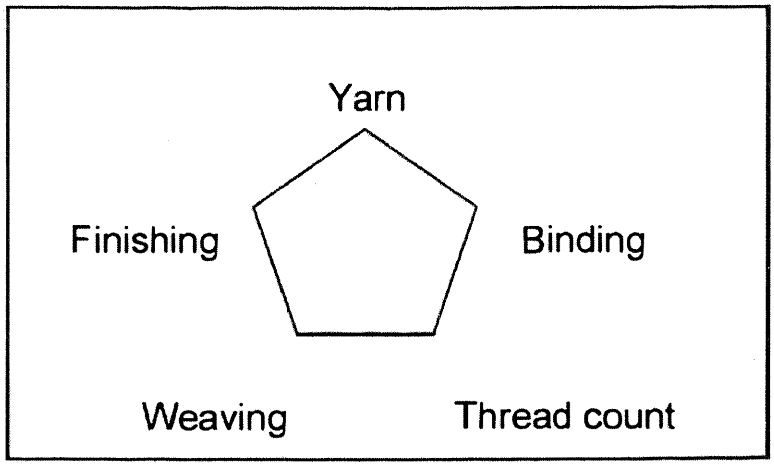

Figure 1. The pentagon system for visual grouping of textiles (Image © Hammarlund. Courtesy of (Hammarlund 2013, p. 179, fig.67).

Where full garments survive or are known from iconography, full preservation or written records, researchers can investigate the visual and haptic sense of wearing clothing, and others' perception of the clothed person. As well as the visual sensations of colour, pattern, shape and design, clothing has multiple haptic sensations of softness, warmth, firmness, scratchiness, comfort in fit, sensations of restriction and movement, and emotional responses to suitability (Rösel-Mautendorfer, 2015, p.125). Examining the stitching of the man's costume from the Early Bronze Age Danish oak coffin burial of Trindhøj, dated 1347 cal. BC, archaeologist and tailor Helga Rösel-Mautendorfer observed two pieces of textile stitched on the bias (where one fabric is placed at an oblique angle to the other). Such tailoring adapts to the body and allowes better body movement (Rösel-Mautendorfer, 2015, p.127). More broadly wrapped or tailored clothing affects a person's movement, as with the notoriously impractical toga of imperial Rome, that was so unwieldy that the wearer required two dressing assistants (Goette, 2013, pp.41–43). The appearance of the toga, whether too thin, too bright, too shiny, too sweaty or too yellow, provided Roman satirists with an endless source of fodder to poke fun at, and pass moral judgement on the officials who wore them (Harlow, 2018, pp.185, 189–190). Here, observation is combined with reflective experience or contemporary accounts to understand the visual, propiroception and vestibular sensations of textile clothing, and judgements associated with them.

Macroscopic observations are readily recorded and published in diagrams and photographs. Inventive presentation techniques aid the presentation of the sensory qualities of archaeological textiles. 3D diagrams of the textile from Kalyvia, in fifth century BC classical Athens, provides an interpretation of weave strucure and texture of this open, transparent and purple dyed textile (Figure 2). The presentation of tessallated squares of cropped textiles from the Bronze and Iron Age textiles of the Hallstatt, Austria (e.g. Grömer, 2016, p.135) reduces the eyes' tendancy to trace the ragged outline of textile fragments and allows the viewer to be intrigued by the colour, texture and pattern (Figure 3). Developments in digital imaging and virtual reality augment the sensory presentation of textiles. For instance, Reflectance Transmission Imaging (RTI) stitches together multiple images of the same object lit from different angles creating a more natural viewing effect than that of a static image (Frank, 2014). The digital gaming industry is creating ever more effective presentation of textiles that clothe mobile bodies, adorn furniture and create avatars for people to be and believe in (e.g. Aliaga, et al., 2015); Basori, et al., 2018). Macroscopic observations of archaeological textiles are the primary means by which sense properties are analysed, presented and perceived. Innovative methods in this area are providing rich resources for enhancing the study and reception of archaeological textiles.

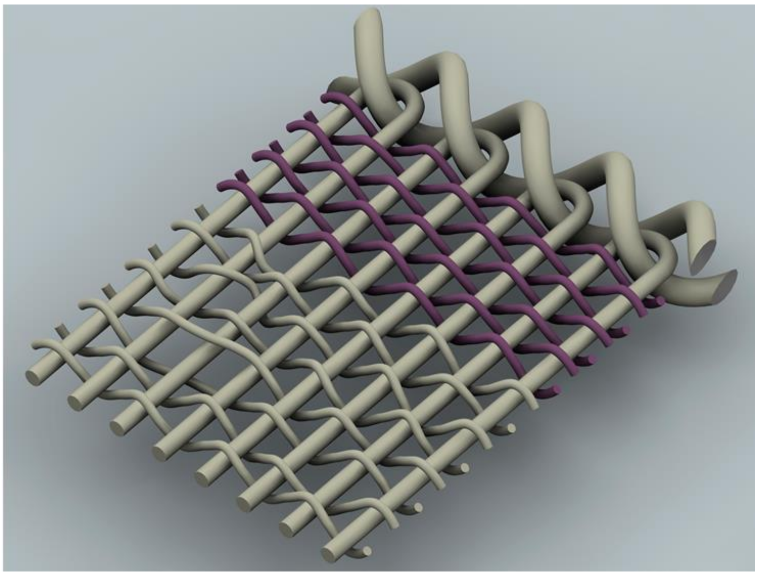

Figure 2. 3D diagram of an open, transparent and purple dyed textile from Kalyvia, classical Athens, fifth century BC. (Drawing courtesy of Stauros Koulis, in Spantidaki, 2016, pp.64, 110, fig.5.23).

Figure 3. Tessalated squares of Bronze Age textiles of the Hallstatt salt mines, Austria, dated 1458–1245 cal.BC (Image © Natural History Museum Vienna, Photograph: Andreas Rausch).

Microscopic

Microscopic analysis, whether using light or scanning electron microscopy, allows observation beyond the capacity of the human eye. While we cannot see at this scale, we can see, hear and feel effects these features create in the textile. Microscopy is the most common method used to identify the fibre used to make textiles (Catling and Grayson, 1982; Appleyard, 1978; Rast-Eicher, 2016). Once the fibre is identified, archaeologists can better understand the natural colour range, lustre, comfort properties and inherent tensile strength of textiles made from these fibres. This is because there are major sensory distinctions between the physical, aesthetic and chemical properties of natural cellulosic fibres (e.g. flax, cotton, hemp), protein fibres of animal hair (e.g. sheep wool, horse hair) and extruded protein fibres (e.g. silk) (Collier, et al., 2009, pp.39–123). Flax, for example is naturally silvery grey or golden in colour and physically strong, rigid and stable in shape, whereas wool ranges from dark brown to white in colour, is lustrous, physically of moderate strength, elastic and insulative (Harris, 2010, pp.105–107) (Figure 4).

Figure 4. The colour and textures of plant fibres. Clockwise from top left: willow (*Salix* sp.*)* bast processed by dew retting, willow bast processed by dew retting and boiling, flax (*Linum usitatissium)*, raffia, lime (*Tilia* sp.*)* bast processed by water retting (Image: S. Harris).

Microscopy can be used to interpret fibre processing and the effect on the sensory properties of textiles. Based on an established method (Ryder, 1969; Ryder, 1983, pp.42–47),Antoinette Rast-Eicher developed a method to grade wool fibres according to the extent to which they were processed to remove coarse fibres (Rast-Eicher, 2008, pp.153–155). This classification grades from the highest percentage of fine fibres (AAA) to those with the least fine fibres (F) (details in Rast-Eicher, 2008, p.155; see also Gleba, 2012; Skals and Mannering, 2014; Christiansen, 2004). Many of the Early Iron Age Danish bog textiles, dated c. 800 BC–AD 400, are made with wool fibre of homogenous fibre diameter with a mode below 20µm, and a large majority at 13µm (1000µm=1mm) (Skals and Mannering, 2014, pp.26–27). These fall into the AAA wool quality and would have been extremely soft (Skals and Mannering, 2014, p.26). These fine fibres are softer that wool fabrics today, which are typically 17–30μm for clothing fabrics (Tridico, 2009, p.37, fig.3.7). Similarly, it is starting to be understood that in prehistoric Europe plant fibres (e.g. flax, nettle) were processed differently to wool fibres, as bast fibres were spliced rather than draft spun (Leuzinger and Rast-Eicher, 2011; Gleba and Harris, 2018). It is likely that this had an effect on the sensory qualities of plant fibre textiles, as plant fibres processed for splicing involved less beating, which could have resulted in finer, more lustrous threads and hence textiles (e.g. Pendergrast, 1996, p.137). In textiles, microscopy is essential for the analysis of fibres and fibre processing. Fibre is the primary material of textiles, in combination with yarn and weave structure, fibre provides a basis to interpret the visual (colour, shine, texture) and haptic (cutaneous, tactile) properties of archaeological textiles.

Scientific analysis

Scientific analyses are methods based in the natural sciences applied to archaeological textiles. They can be used to investigate chemical and physical properties of archaeological textiles, especially those that have been transformed through taphonomy.

Textile colour and coloured patterns are visual sensations that can dramatically change people's perception of textiles. In some cases colour remains visible; however, archaeological textiles are often stained or faded, and preserved colour can be misleading due to the disintegration of dyestuff (Vanden Berghe, et al., 2009, p.1911). As preserved colour cannot be relied upon, colour is analysed through chemical detection of dyes and pigments (e.g. paint on textiles or statues) using chromatography (e.g. High Performance Liquid Chromatography) and spectroscopy (e.g. X-Ray Fluorescence; Scanning Electron Microscopy coupled with Energy Dispersive X-ray). Both result in a chemical 'fingerprint' which is matched to a potential dye or pigment source through reference collections. This source is then interpreted as colour. For example, using HPLC analysis, traces of the dye constituent indigotin were identified in Danish bog textiles dating to the Roman Iron Age (AD 1–400) (Vanden Berghe, et al., 2009, p.1919–1920). Indigotin is the main colourant in woad (*Isatis tinctoria L.*) and indigo (*Indigofera tinctoria L.)* plant dyes (Cardon, 2007, pp.337–340). In the case of the Danish Roman Iron Age, the dye source is identified as woad due to the archaeobotany of the geography and period. On the basis of historical, chemical and ethnographic knowledge, woad is usually interpreted as a blue dye (Cardon, 2007, pp.342–349). However, an experiment on woad found a wide range of colours that can be produce when dyeing with this plant, from the expected shades of blue to grey, beige, mint and pink (Hartl, et al., 2015, pp.20–24). Such dye experiments create reference collections to better understand the relationship between the dye constituents detected by chromatographic and spectroscopic methods and the resulting colour of the original textiles (Hartl and Hofmann-de Keijzer, 2005; Hartl, et al., 2015). These colour experiments help researchers address subtle variations in chemical analysis and the interpretation of the analysis of visible colour from dye compounds.

The drape, strength and density of textiles influences the handle and appearance of textiles. In the textile industry these mechanical or physical properties of textiles are measured using standardised tests (e.g. Saville, 1999). As archaeological textiles cannot be tested directly, mechanical tests are carried out on modern equivalents. The drape of a textile is the measure of how it folds and falls under its own weight. Broadly, loosely woven textiles woven with fine yarns are floppier than similar densely woven textiles woven with coarse yarns. This drape affects the sensation of movement of freely hanging textiles. Tests to examine the drape of Roman military textiles of the Rhine province, Germany dated to 5 AD, considered two parameters: drape coefficient (depth of drape) and the number of folds. In their analysis of fine quality textiles woven with cotton, linen, silk and sheep's wool, the results demonstrated that linen was the stiffest with the lowest value for the number of folds, and highest value for drape coefficient (i.e shallowest drape). Wool had the highest value for the number of folds, whereas silk showed the lowest value for the drape coefficient (i.e deepest drape) (Figure 5) (Mitschke, 2013, p.231, fig.4). The strength and durability of fibres, yarns and textiles are measured using tensile tests to measure the breaking strength (tensile strength), deformation when force is applied (Young's modulus) and the work required to break the material (toughness) (Harris, et al., 2017, pp.582–583). Comparison of a range of plant fibres species (flax, lime bast, willow bast) used across Europe in the Neolithic, c. 4000 BC, showed that strips of flax fibres when dry were stronger and tougher than strips of tree bast fibres; when wet, they showed little difference (Harris, et al., 2017, figs. 3–5). This mechanical information has implications for haptics of force feedback, as the strength of textiles is felt in the resistance of the muscles, for example when carrying a bag or dragging a net. The density or translucency of a textile, and related to this its permeability or lack of it, is referred to as cover factor (Collier, et al., 2009, p.42). Accurate measurement of cover factor was used to identify the characteristics of preserved fragments of Viking sails, and enabled modern weavers to produce effective woven wool sails for replica ships (Cooke, et al., 2002). These analyses found that the ability of the replica sails to fill with wind depends on the correct cover factor and dressing (*smörring*) of the wool textiles.

Figure 5. Drape testing to investigate the quality of cloth used by the Roman military in Rhine provinces, Germany, ca. 5 BC. Clockwise from top left: fine textiles woven with linen, wool, cotton and silk (Images © J. Christen. . Quality experiment DressID, 2009 by S. Mitschke, Curt-Engelhorn-Centre Archaeometry, Mannheim, A. Paetz gen. Schieck, Deutsches Textilmuseum Krefeld in cooperation with A. Stauffer, University of Applied Sciences Cologne).

Reconstruction and experimental archaeology

Reconstructions are often made for exhibition or costume events. Experimental archaeology involves the simulation of textiles or textile production processes to test a research hypothesis. Both provide opportunities for sensory investigation.

Textile clothing is more than an assemblage of materials and garments, it profoundly changes the sense of self, the sensations of the body, and a person's capacity to act. Experiments can be used to investigate the sensory experience of clothing. For example, from the seventh to second centuries BC warriors of the Eastern Mediterranean wore the linothorax or linen corselet, a type of laminated linen armour (Aldrete, et al., 2013, pp.11–20). According to iconographic and written evidence, the linothorax was intended to protect its wearer against missile attack (Aldrete, et al., 2013, pp.95–97). To test its effectiveness, Aldrete et al. (2013) assimilated research on ancient materials to construct a linothorax and arrows, then fired the arrows at the armour using modern ballistic testing equipment and recorded their penetration, and hence the likelihood of protecting the wearer from fatal injury. Compared with metal armour, or no armour, the laminated linen armour proved surprisingly resistant to arrow attack (Aldrete, et al., 2013, pp.103–104, 113–115). Such results increase our understanding of the sensorial effects of linen cloth in the ancient Greek, Macedonian, Etruscan and Roman world. In classical literature, linen cloth is typically associated with garments such as the full-length *chiton***—**a fine garment that hung in close folds (Lee, 2015, pp.106–110). The results for the linen corselet experiment reminds us that linen textiles were part of a dynamic sensory world, where flax could be spun, woven, stitched and glued into laminate armour or delicately folded and draped on the body as a white, radiant garment.

Experiments provide an immersive sense experience for those involved, yet rarely is this experience the focus of the experiment. In investigating the cloth cultures of Late Ertebølle hunter-gatherers of southern Scandinavia, dated c. 4000 BC, a collection of replica fibre and fur fabrics were assembled based on the archaeological evidence (Harris, 2014, pp.41–44). The standard classification of these materials is by their technological classification, such as 'couched button-hole stitch with extra turn in the button-hole stitch' (Bender Jørgensen, 1990, pp.2–4). While these classifications are correct and important, they mean little to general readers, most of whom will have had no previous contact with these fabrics. To describe the sensory properties of these materials, the author set up a handling experiment, where a group of participants were asked to answer questions on the visual appearance, sound, smell and touch properties of the cloth replicas (Harris, 2014). These group results were then used to create sensory descriptions of cloth. For example, couched button-hole stitch made with tree bast fibre is described as visually uneven, matt, and transparent, with a weak grassy, woody or sappy smell, cool and rough to the touch, flexible, stretchy and thin to handle, with a rustling, crackling scratching sound (Harris, 2014, p.47, tab.2). These fabrics and people's sensory response to them through the experience experiment capture significant parameters for the way people engage with fabrics, which are not otherwise available in the archaeological literature. They refocus attention on the perception of materials across the senses and generate questions of ancient sensory cloth worlds.

Clothing reconstruction has the potential to provide reflexive multi-sensory experiences of textiles for many people, including academics, museum visitors, curators and the craftspeople involved in making them. In the West Berkshire Museum, England, a dressing up activity presents a chronologically ordered clothing rail. Trying on the clothing, people can experience for themselves cloth of the Iron Age, Roman period and sixteenth to nineteenth centuries (Figure 6). While textile reconstructions have a long history in research and exhibition display, the practice of reflecting on this process is a recent development (Demant, 2017, p.33). For example, Ida Demant and Anna Batzer were commissioned to make a set of clothing as represented on the 'Dama de Baza', the statue of a woman from the Iberian town of Baza, Granada, Spain, dated to the third century BC (Alfaro Ginner, 2013; Demant, 2011, p. 37). In their account of this process there is an oscillation between the visual observation of form, pattern and colour traces on the Dama de Baza statue, and the decisions about drape, fibre, weave structure, colour and shape of the textile garments they weave (Figure 7). To choose the fibre for this garment, Demant and Batzer selected wool because 'Linen is a soft and smooth material which would have been nice to wear close to the skin, whereas wool worn as the outer layer would have offered insulation against both heat and cold' (Demant, 2011, pp.37–38). To create the visual appearance of the folds of the mantle represented on the statue they learnt through trial and error that to fit a woman 160 cm high there must be an upwards curved edge of a semi-circular shape, 230 cm long, with a maximum 140 cm depth (Demant, 2011, p.38). Here there is an explicit connection between the presentation of haptic and visual properties of the clothing on the statue and its reconstruction. Seeing the woman in the statue beside the woman in the reconstruction (Figure 7) highlights the profound sensory effect of these textile garments.

Figure 6. Dressing up activity providing participants with a fully emersive sensory experience. These are replica garments in a museum display which provide a sensory time line from the Iron Age to the nineteenth century (Image: S. Harris, courtesy of the West Bershire Museum).

Figure 7. Left: Dama de Baza, painted statue of a woman from the Iberian town of Baza, Granada, Spain, third century BC (Image © Museo Arqueológico Nacional. Photo Fundación ITMA). Right: Textile clothing replica of the Dama de Baza (Image © Lejre Land of Legends, Ole Malling, Textile replica A. Batzer and I. Demant, Model H. Carslund Andersen).

Over the last decade there has been substantive research into the relationship between textile production tools and the threads or textiles they were used to produce (Andersson Strand, et al., 2008; Kania, 2013; Hudson, 2014; Verhecken, 2013). For example, to investigate the types of yarn that can be spun with a spindle, two experienced spinners spun wool and flax yarn using copies of conical and biconical spindles whorls weighing 4g, 8g and 18g from Bronze Age Nichoria, Greece (Andersson Strand, 2012). The results led the researchers to conclude that although there were differences between the yarns produced by either spinner, the weight of the spindle whorl produced the most difference in the finished yarn (Andersson Strand, 2012, pp.208–209). By contrast, in another experiment the results suggested that the greatest influence on yarn was the spinner, rather than spindle weight (Kania, 2013, pp.25–27). While such results stimulate debate on the relationship between tools and yarns, the factors that define these processes reveal finely tuned haptic sense experiences. Spinners flick the spindle to impart rotation; at the same time they control the draft of fibres into the yarn, and need to constantly adjust to changes in the total weight of the spindle as a fresh yarn is wound around the spindle shaft (Verhecken, 2013, pp.99–100). These movements are defined by the mechanics of fibre friction, torsion, fibre stress-strain properties, twist intensity, density and packing (Verhecken, 2013, pp.99–100, tab.1).

Using the computer application Motion Capture (MoCap)—a video movement analysis—reveals the full body engagement in spinning where irregularities in hand and arm movement result in spindle wobble and irregular yarns (Andersson Strand, et al., 2016, pp.12–13). We may describe this as tacit knowledge; the knowledge craftspeople have which is based in the experience of bodily relationship with materials, processes and effects (Bender Jørgensen, 2015, pp.91–94). From these combined experiments, it is apparent that spinners control yarn production through tacit knowledge of the full array of visual and haptic senses: proprioceptive, vestibular, kinaesthetic, cutaneous and tactile. When we look at contemporary yarn we see the result of these individual spinners' haptic skill and tacit knowledge of spinning. Consequently, if we consider the consistency of yarn product across a culture together with the huge quantity of yarn that was produced, we start to recognise large groups of individuals who shared haptic knowledge of spinning fibres into yarns.

Sense properties: moving forward

These methods demonstrate the approaches researchers use to investigate and describe the sensory properties of archaeological textiles. To make a substantive change across textile archaeology these methods need to be carried out and published to accepted standards and widely. For some techniques this will require specialists to learn new skills or to work in teams. Ultimately, the aim is to include descriptions of sense properties within descriptive texts and textile catalogues[1]. This is already underway; for example the catalogue of textile from the Hallstatt salt mines includes wool qualities, cover factor, stitching, dye compounds and visual grouping (Grömer and Rösel-Mautendorfer, 2013). Other forms of analysis, such as an evaluation of fabric drape, handle, smell, sound and sheen require further development before they can be widely applied to archaeological textiles. If '... archaeological scientists

[1] Thanks to Ben Elliott for an interesting discussion on this proposal.

are no longer simply providing “data” on the characteristics of materials. Instead they are explicitly concerned with how the properties and qualities of materials relate to past human lives’ (Jones.A.M., 2015, pp.335–337), then a sensory textile archaeology needs to consider these cumulative data within the interpretive narrative. One of the ways to achieve this is through the sensory engagement of people and things.

Sensory textiles into the interpretive narrative

> ‘Each culture creates its own sensory environment, both physically through construction a material world with its own set of sensory properties and culturally through emphasizing and valuing certain types of sense impressions over others’
>
> (Gosden, 2001, p.166.)

With increased recognition of the sensory properties of archaeological textiles, the next stage of interpretation is more profound. These cumulative data on textile sense properties can be used to question how past people used textiles to construct and structure their material worlds. Here archaeologists are investigating ‘worlds of sense’ where sensory experience is culturally and socially ordered (Classen, 1993).

Sensuous environments are constructed in past societies through the routine use of textiles and other types of cloth for clothing. Sensations of clothing are cultural, and past clothing worlds can be challenging to modern sensibilities. Textile archaeologists are frequently asked: ‘What did they wear?’ And the answer is often followed with the reply, ‘Surely that was uncomfortable/impractical?’ This exposes an underlying cultural expectation of what can or should be worn close to the skin, and how. Indeed, past clothing can be challenging to modern sensibilities. When the frozen Iceman (Ötzi) dated 3300 cal.BC was discovered on the Italian/Austrian border, archaeologists were surprised by the absence of textile clothing (e.g. Barfield, 1994; Spindler, 1995, pp.132–133). Large pieces of twined grasses and tree bast (a type of flexible basketry) found under the head and chest of the Iceman were interpreted as a cape (Figure 8). To interpret the use of this twined fabric, archaeologists pointed to complete hats and sandals of similar manufacture from the Late Neolithic alpine lake dwellings (ca. 4000–2400 cal. BC), and comparable materials used for nineteenth and twentieth century raincoats, cloaks and tunics (Feldtkeller, 2004, pp.61–62; Médard, 2010, pp.92–98; Putzer, 2011, p.29). Qualitative and quantitative sentient data on these materials is available through replica garments (Reichert, 2006), climate control tests (Gortan 2012) and tensile tests of fibres (Harris, et al., 2017). Yet a present day audience used to soft, smooth, floppy industrially produced textiles, receive the idea of twined plant fibre clothing with disbelief. When handling such fabrics, some consider them scratchy and painful on the skin (Harris, 2014, p.51). Twined clothing demonstrates the otherness of the haptic world of prehistoric Europe, and how the sensory world is constructed in unexpected ways. It also demonstrates the strength of sensory prejudice when faced with unfamiliar materials. In this vein, one wonders how people first received unfamiliar woven textiles into their clothing assemblages.

Figure 8. Left: large pieces of twined grasses and tree bast found under the head and chest of the Iceman, interpreted as a cape (Image © South Tyrol Museum of Archaeology). Right: reconstruction of the Iceman wearing fur and leather belt, leggings and shoes (Reconstruction by Kennis: © South Tyrol Museum of Archaeology/Augustin Ochsenreiter).

It is not only unexpected clothing materials that are challenging. The failure to clothe certain body parts (buttocks, breasts, genitals) is quietly censored. The statuette of a women wearing an open bodice with long flounced skirt from Knossos, Crete (c. 1650 BC) is typically replicated with a textile panel covering the breasts (Nosch, 2008, pp. 6–11; with exceptions: Jones.B.R., 2015). The string apron which hangs beneath the buttocks of the Upper Palaeolithic 'Venus' figurine from Lespugne (c. 20,000 BC) (Barber, 1991, p.40) is not replicated on live models and speaks of its complete sensory otherness. Such censorship attests to the inherent conformity of clothing environments, and the relationship between visual perception and cosmology. In these and numerous other examples (e.g. Figures 6 and 7), the sensations of ancient textiles and clothing are disruptive. The audience are drawn into the otherness of the haptic, visual, olfactory and auditory worlds of prehistoric Europe. The unfamiliarity of apparently routine sensations of clothing encourages people to pay attention.

In other cases, the sensations of cloth are more familiar and accessible. Through sensations of colour, drape, softness, shine, weight, smell, transparency and texture, textiles have conspicuous sensory appeal. This sensory appeal is desirable and can be valuable because colour can be used to influence the perceptions, attitudes, symbolism and behaviours of others people (Harris, 2017, pp.688–690). Take for example purple dyed textiles. Textual and archaeological evidence indicate that purple textiles were appreciated and traded across the Mediterranean and Near East from the mid-second millennium BC onwards (Soriga, 2017, pp.79–82). According to classical texts, the most desirable colour shade range—with its characteristic smell—was a shellfish dye from Tyre (Ovid, *Art of Love*, 3.171–172; Croom, 2010, p.16). This deep red, blue and purple dye is extracted from the gland of marine molluscs of the Muricidae family (Cardon, 2007, pp.443–557). Chemical analysis detects that the brominated compounds derive from shellfish dyes, and enables researchers to separate them from purple achieved by plant dyes (Gleba, et al., 2017, pp.135–136; James, et al., 2009, p.1112). Gas chromatography mass spectrometry – olfactometry (GC-MS-O) has the potential to detect the legendary smell (Cooksey, 2017, p.77). Requiring ample mollusc glands and skill to produce, it was a rare and precious dye. In the Bronze and Iron Ages 'royal' purple was a luxury of kings, deities and aristocrats; its colour and smell were a symbol of social and economic status (James, et al., 2009, p.1116; Soriga, 2017, p.79). In Classical Rome, purple dyed garments, stripes and motifs were popular and luxurious items (Croom, 2010, pp.24-26). By the Hellenistic period (fourth to first centuries BC) even quarry workers and soldiers could afford some purple (Gleba, et al., 2017; Paetz gen Schieck, 2012). In the Late Roman period (fourth century AD) sumptuary regulations restricted purple robes (silk dyed with shellfish) to the Emperor, with contravention of the law punishable by death (Croom, 2010, p.26). Over this long time period, the availability, value and symbolism of the colour and smell of purple textiles structured changing concepts of luxury, power and wealth. Similar narratives of coloured textiles are found across the globe, showing that the sensations of textiles have consequences.

There are horizons of major sensory shifts in textiles. In the Early Iron Age across central Europe textiles became increasingly refined. During the Hallstatt period (800–400 BC) in Central Europe, textiles in well-furnished (princely) graves and the Hallstatt salt mines are more frequently dyed, threads become finer, thread counts higher, pattern and decoration more intense (Grömer, 2014; Banck-Burgess, 2012). Like Central Europe, in Italy during the first millennium BC textiles were fine, patterned and colourful. There is a preference for twill textiles, which contrast to the visual and haptic aesthetic of contemporary weft-faced tabby textiles of Greece (Gleba, 2017, pp.1210–1214). The weight and lustre of textile clothing may have been significant. Across Europe and the Mediterranean in the Early Iron Age bronze ornaments and amber were added to textiles. For example, many hundreds of bronze buttons were found attached to a woman's burial outfit in grave 27, mound 48 at Stična, Slovenia (Hullmuth, 2008[2010]). These would have made the garments glitter, as well as making them heavier. Compared with several generations before, the sensory world had shifted. Does this matter? The Early Iron Age, with its early urban centres and *oppida*, is a time of increasing social complexity and hierarchies. Fine, patterned and colourful textiles would have been expensive and exclusive because of the resources and huge amount of skilled work required to spin, weave and dye (Harris, 2017, p.688). In Etruscan iconography (seventh to sixth centuries BC), colourful, patterned, draping textiles are flaunted at aristocratic social events such as the banquet (Harris, 2017, p.690). That textiles structured power and inequality is evident in the well-furnished graves of the Late Hallstatt period, where bodies and objects were lavishly wrapped in multiple fine, patterned, colourful textiles (Banck-Burgess, 2014, pp.151–153). Here sensational textiles readily highlight those with access to them; they structure notions of power, context and belonging.

More complex to recognise are the cosmological worlds that were largely unconscious, such as those that surround the position and movement of the body in textile production. Consider the production of square sails for Viking Age ships, the hulls of which have been excavated from sites including Roskilde, Denmark and Hedeby, Schleswig-Holstein, Germany (eighth to eleventh centuries AD) (e.g. Crumlin-Pedersen, 1997; for square sails see Kastholm, 2007; Bischoff, 2017). There are rare surviving fragments of woven wool sail-cloth which were reused as packing for church roof planks in Trondenes, Norway. One of these, Trondenes T06, includes a stitched rope sail eyelet, attesting to its former use as a sail (radiocarbon dated to 1280–1420 cal. AD) (Cooke, et al., 2002, p.204) (Figure 9). As mentioned above, analysis of these textiles combined with sail experiments has recognised the technical consistency (fibre tenacity, weave, cover factor, smörring/dressing) of these sails (Cooke, et al., 2002, pp.205–207). Production experiments estimate that a sail for a single warship took the equivalent of one person nine working years to spin and weave (Bender Jørgensen, 2012, p.178). That there were hundreds of sailing ships for war and trade attest to the widespread haptic, visual and tactile skills in preparing wool, spinning and weaving in the population at the time. The crew depended on the quality of the sail and its rigging, as failure would be fatal to the crew, ship and cargo (Crumlin-Pedersen, 1997, p.188). This raises questions as to the cosmological sense worlds of those people who spent much of their lives spinning and weaving to produce consistent, standardised fibres, yarns and textiles for sails.

Figure 9. Reconstruction of five Viking sailing ships, Skuldelev, Roskilde Fjord, Denmark (Image © The Viking Ship Museum in Roskilde).

Sensory Textiles into the Future

This chapter has provided an extensive review of the innovative approaches to sensory textiles developed by a wide range of researchers and research teams. I encourage the reader to make connections to sensory textiles and textile research of other periods and continents. For the first time, this chapter brings a sensory archaeology of textiles into a coherent body of approaches and narratives. What becomes apparent is that a sensory approach to textiles is ideally suited to investigate archaeological fibres and fabrics, garments, equipment and furnishings, because sensations define people's relationship to these materials and through them, their relationship to each other. A sensory approach to materials is based in a major shift in the humanities, the ontological turn, where subjects and objects share agency (Latour, 1999, p.180). In other words, with textiles (raincoats, cloaks, sails, purple silk, etc.), we are different people. With the 'right' textiles people of the past were able to do different things, and be different men, women and children. They could be appropriately dressed, gain power and influence, be transported across the seas, and be more or less than someone else. In short, while a sensory archaeology of textiles provides an original methodological basis to analyse source materials, it also challenges archaeologists to question the effect of textiles on people in a fresh and exiting way. For this, a sensory archaeology of textiles has broad relevance to archaeologies of all times and places, as textiles, cloth, and the closely related field of clothing are fundamental to human societies; and the basis for their effects is sensation.

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