Smell of Heritage

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Doctor of Philosophy (PhD) thesis

1 Signed declaration

I, Cecilia Bembibre Jacobo, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

2 Dedication

To Stuart, Logan and Fiamma, for making every day an adventure.

3 Abstract

We don’t know much about the smells of the past. Yet, odours play an important role in our daily lives: they affect us emotionally, psychologically and physically, and influence the way we engage with history.

Can this lead us to consider certain smells as cultural heritage? And if so, what would be the processes for the identification, protection and conservation of those heritage smells? In order to answer these questions, the connection between olfaction and heritage was approached through the framework of Significance Assessment – Chemical Analysis – Sensory Analysis – Archiving.

Four case studies were developed, each around a different smell: old books and historic libraries; scented conservation wax, historic pot-pourri, and mould. Through them, the validity of the framework was tested, while exploring associated aspects of olfaction in heritage: authenticity, value in connection with visitor experience and interpretation, considerations around historic odour reconstruction and role of non-sensory input in historic odour perception. Odour characterisation was achieved by chemical analysis of the volatile organic compounds (VOC) for each case study, using either HS-SPME-GS-MS or HS-TD-GC-TOF-MS. Sensory characterisation was obtained via GC-O and odour evaluation panels. Visitor experience surveys were also conducted in a historic house setting. Smells were documented using odour wheels and other forms of visual representation. Some findings of this study worth discussing are: (1) the perception of authenticity in historic odours is not necessarily linked to a chemically-accurate reconstruction; (2) several historic odours present an ambiguity that lead to characterisation being significally modulated by both sensory and non-sensory information and (3) there is a great potential for non-visual engagement of visitors with the space and collections in heritage institutions, currently untapped. This is the first systematic study of olfaction in heritage and therefore its insights will be relevant to the heritage community, as well as engaging with current research in the field of odour perception, interpretation and representation.

4 Impact statement

Figure 4-1. Selection of images from press, public speaking, social media and heritage exhibitions illustrating impact of this project between 2016 and 2019.

4.1 Heritage impact

I presented this project at key heritage events, such as the Discovering Collections, Discovering Communities conference (DCDC16), International Committee of the Council of Museums (ICOM CC) 18th Triennial Conference, the Universidad Complutense in Madrid and The National Archives of the UK. The National Heritage Science Forum, Christ Church Heritage and The Smithsonian found the research of interest to readers of their blogs.

In addition, my findings have been included in a number of heritage exhibitions:

- Knole's Conservation Studio (Knole, 2018)
- Conserving and Preserving (Anglesey Abbey, 2018)
- Conservation 50 (St Albans Museum + Gallery, 2019)
- The Barking Stink - the industrial heritage of the River Roding (The Thames Trust, 2019)

4.2 Academic impact

My investigation was featured as a case study in the Doctoral Centre Report by The Engineering and Physical Sciences Research Council (EPSRC, 2017), and the UCL Institute for Sustainable Heritage Annual Report (UCL ISH, 2017) highlighted Olfaction in Heritage as a developing field of study.

My published work has been cited 10 times to date in chemistry, conservation, archaeology and heritage studies peer-reviewed research papers. I published three articles during the PhD, one of which (Bembibre and Strlič, 2017) has been accessed over 15,000 times and is in the 99th percentile in terms of Attention Score compared to all outputs of the same age (Altmetric Attention Score, 2019). Another one was published as conference proceedings (Bembibre Jacobo, C; Barratt, S; Vera, L, Strlič, 2017) and a third one as a book chapter (Bembibre, C.; Strlič, 2017).

During this project I engaged in a conversation with the wider academic community, including lecturing at Aarhus University's School of Architecture and giving a keynote address at the Royal Society of Chemistry Analytical Biosciences Early Career Researcher Meeting. I was also invited to present at the Centre for Research in the Arts, Social Sciences and Humanities (CRASSH) in the University of Cambridge and at the UK SemioChemistry Network annual workshop. Two of my posters about olfaction in heritage won awards as best in conference: at the IV International Congress on Chemistry for Cultural Heritage and the II International Conference on Science and Engineering in Arts, Heritage, and Archæology (SEAHA).

Springer Nature produced a video interview about my research, and the historic book odour wheel has been discussed online by researchers concerned with olfactory visualisation (Noppeney, 2017).

In addition to the partnerships (Knole, Odournet) set as part of the PhD, I have established new collaborations with heritage scientists at the University of Economics in Cracow, archivists at the Osmotèque museum in Versailles and with London-based perfumer Sarah McCartney.

In regards to the present work, sections of Chapters 8 and 9 have been published as Bembibre, C. and Strlič, M. (2017) 'Smell of heritage: A framework for the

identification, analysis and archival of historic odours', *Heritage Science*. doi: 10.1186/s40494-016-0114-1; the authenticity study will be published as part of the article Bembibre, C. Authenticity in historic smells. Mediality of Smells, Cultural Interactions, Peter Lang, publication scheduled for the autumn of 2020. Sections of Chapter 10 have been published as Bembibre Jacobo, C; Barratt, S; Vera, L, Strlič, M. (2017) 'Smelling the past: a case study for identification, analysis and archival of historic pot-pourri as a heritage smell.', in Bridgland, J. (ed.) *COM-CC 18th Triennial Conference Preprints*. Paris: International Council of Museums, p. p. 1601 and sections of Chapter 12 are currently in preparation as an article co-authored by the team at the University of Cracow.

4.3 Industry impact

The knowledge exchange during the PhD resulted in the following impact in industry:

- Development of expertise in VOC sampling in historic settings, such as effective SPME fibre exposure and Tenax sample volume,
- Training in descriptors to characterise historic odours,
- Novel application of GC-O in heritage, with one published article with industry and two other in preparation as a result (Bembibre et al 2017; Bembibre et al, 2020a; Bembibre, et sl, 2020b).

4.4 Public impact

My exploration of smells with cultural value was covered by national and international press in the period between November 2016 and January 2019, featuring in over 350 outlets including BBC News, The Guardian, The Telegraph, Channel 5's *Secrets of the National Trust* documentary series, CNN, Newsweek, El País, La Repubblica and Die Zeit. Furthermore, I reached a wider audience via talks at TEDx and Mediamatic's Odorama series. The study on the smell of books was also featured in a design book (Freudenberger, 2019).

A website (www.smellofheritage.org) and a social media account (@ucqbbem Smell of Heritage) have been communicating the aims, methodology and progress since the beginning of the project.

5 Quotes

Let us not overlook the further great fact, that not only does science underlie sculpture, painting, music, poetry, but that science is itself poetic… Those engaged in scientific researches constantly show us that they realize not less vividly, but more vividly, than others, the poetry of their subjects.

(Spencer, 2010)

These ambiguities, redundancies and deficiencies remind us of those which doctor Franz Kuhn attributes to a certain Chinese encyclopaedia entitled The Celestial Emporium of Benevolent Knowledge. In its remote pages it is written that the animals are divided into
a. belonging to the Emperor
b. embalmed
c. trained
d. pigs
e. sirens
f. fabulous
g. stray dogs
h. included in this classification
i. trembling like crazy
j. innumerable
k. drawn with a very fine camelhair brush
l. et cetera
m. just broke the vase
n. from a distance look like flies

(Borges and Simms, 1964)

6 Table of Contents

7 Introduction

Every day, we perceive hundreds of smells. They affect the way we feel, we think, and we behave. There are smells that instantly bring up our own childhood and olfactory memories that we share with a whole generation. Scents are often anchored in the identity of physical spaces, to the point that sometimes a place seems less familiar when it does not smell as we expected. We smell in our home, in the street, in the museum: the information we receive through the nose impacts every aspect of our life, including the way we experience history.

In many ways, smells are intrinsically linked to heritage. We inherit the smells of the past in the descriptions of historic practices or places, as traces in heritage artefacts, as documented formulas of a long-lost perfume. We get information via our nose when we step into a heritage library, breath the subtle perfume of the wax that protects the surfaces of a historic house, bury the nose in a pot-pourri designed 250 years ago or wonder about decay upon sniffing the smell of mould.

And yet, unlike other embodiments of heritage such as buildings or the skills of communities, smells with cultural value are not identified, documented or protected by heritage organisations and guidelines. There is no archive of smells of significance, either. Scents associated with places, objects, practices or threatened flora are a memory in a personal record, a mention in a historic text or simply disappear once the source is gone.

The notable exceptions, where individual or group efforts to identify and document olfactory heritage have been made, either lack a systematic approach or are insular projects and would benefit from a formal connection to heritage to reveal their value.

The purpose of this thesis is to address the absence of a framework to investigate smells with cultural significance. I propose that some smells are part of our cultural heritage, and that a structured approach to researching them is required.

The following questions guide the work:

1. How can a heritage smell be defined from the historical, curatorial or popular point of view?
2. How can heritage smells be identified, analysed and documented?
3. What metadata is needed to effectively preserve a heritage smell, subjectively or objectively?
4. What value does smell contribute to the way the public interact with a heritage site or exhibit?

In order to address these questions, the connection between olfaction and heritage will be explored as follows:

In the Smells and heritage chapter, heritage smells will be defined and their importance argued, by focusing on the following: (1) a theoretical review of olfaction and odours in heritage, including (a) the role of smells in heritage documents and guidelines, leading to the identification of smell as part of cultural significance of a place or object, (b) a review of existing projects where historic, endangered or culturally relevant smells are considered, and (c) the use of historic smells in a heritage context as a means to engage and communicate with the audience; and (2) techniques for identifying, analysing and documenting smells and therefore enabling their characterisation and preservation. These techniques can be approached from two complementary angles: firstly, the chemical analysis of the source of sensation, in our case chemical analysis of the volatile organic compounds (VOCs) that lead to perception of the smell. Secondly, sensory characterisation of that smell in terms of human perception. In the case of historic smells, this dual approach can contribute to a holistic understanding of what the odour represents in terms of the nature, history and state of the object.

The opportunity for policymaking will be shown by providing examples of successful documentation of cultural smells around the world, and how these had a positive impact on tourism, local communities and protection of know-how.
The following chapters comprise a series of case studies around heritage smells, presenting both experimental data and relevant discussions concerning the connection between the olfactory and heritage.

The first of these experimental chapters is titled Inhaling Knowledge. In it, I focus on the smell of old books and historic libraries as a first step into validating the proposed framework to identify, analyse and document heritage smells. In addition to the chemical and sensory characterisation, an odour wheel as a tool for documentation is proposed, in the context of a review of the use of wheels in olfactory research, expert training and public engagement. The question of authenticity in odour reconstruction, fundamentally connected with the idea of bringing back smells of the past, is also explored in this chapter. This is done in a study comparing people's perceptions of two versions of the scent of old book and historic library: one prepared in the lab following an extraction from the odour source, and another one product of a perfumer's interpretation.

The importance of the odour wheel as a documentation tool, in spite of its limitations, will be highlighted for its practicality, simplicity and familiarity. Also, the value of interpretation in heritage odour reconstruction will be argued and presented in the context of the possible applications in heritage.

The chapter titled Smelling the past deals with the smell of the historic pot-pourri used in a historic house. The scent is characterised both in the lab and by a panel in the historic house, beginning an exploration of the role that smells can play in engaging the public, helping interpret collections and presenting a more holistic approach to heritage. The question of value is further discussed in the context of the sensory experiences of visitors to a historic house, after two scents connected to the history of the property were added/highlighted in the showrooms.

Following the findings about the role of smell in the visitors' experience, I will show the opportunity for heritage spaces to develop narratives and engagement with the public in connection with smells.

In the following chapter, Visible and Invisible, the principles and some approaches to odour preservation as practice are discussed, including methods for recreating historic odours. Also in this chapter, the smell of conservation wax is characterised by chemical analysis and expert and non-expert sensory panels, further testing the research framework proposed in this thesis. I will show evidence of how hedonic perception of a historic odour can be affected by the non-sensory information provided at the time of perception, a finding of importance for those considering the use of historic scents for public engagement and as part of collection interpretation.

The final experimental chapter, titled A musty odour, deals with the odour of mould and its significance to heritage. The characterisation of this odour is complemented by a sensory experiment where three different versions of the smell of mould, mediated by semantic labels, were interpreted by a trained panel. Following the experiment's findings, I propose practical ideas to encourage open interpretation of heritage smells in context.

Finally, I include a Methodology chapter with a detail of the methodological approach for this work. One of the most inspiring aspects of this PhD project has been working with a variety of research methods and data. The chemical aspect of odours was approached using analytical chemistry methods for VOC sampling and analysing such as Headspace-Solid Phase Microextraction followed by Gas Chromatography-Mass Spectrometry (HS-SPME GC-MS) and Headspace-Thermal Desorption followed by Gas Chromatography-Time-of-Flight-Mass Spectrometry (HS-TD GC-ToF-MS). Sensory characterisation was achieved via methods such as expert and non-expert panel evaluation using Likert Scales and Polarity Profiles and Gas Chromatography-Olfactometry (GC-O). Self-reported questionnaires (presential and remote) were used to gain understanding on the way a heritage smell can be perceived as authentic; surveys were also used to collect data on the visitors' experience in a historic house. Semi-structured

interviews were conducted with smell reconstruction practitioners. Odour reconstructions were performed by mixing representative odorous compounds (referenced from our own analysis and from published literature) in dipropylene glycol (DPG).

Avoiding reduction and aiming for generalisable results was one of the objectives for this study, which faces limitations imposed by the available technology and expertise (for example, only a limited number of smells perceived via GC-O can be corresponded to chemical compounds identified in the GC-MS analysis, partly due to the diversity of analysed odours in a task where accuracy is improved by training and repetition).

In addition to the inspiration provided by Knole House and St Paul's Cathedral, the heritage spaces where case studies were developed for this thesis, the two quotes that open this work were particularly helpful. On one side, the idea that a highly interdisciplinary enquiry such as this one is underpinned by a common spirit that goes beyond fields and methods ("the poetry of the subject", to cite Spencer), which aims to make sense of a subject by approaching it from different angles and developing a meaningful interpretation. On the other side, the flexible nature of the documentation tools proposed such as odour wheels and treemaps, which should be considered a work in progress, to be interpreted within the accompanying regional and historic context to avoid the risk of becoming, as Borges' listing of Chinese animals, absurd compendia which tell very little about their original culture.

7.1 Illustrative material

A final note to the readers about the inclusion of seven vials with scented material as part of the thesis. These are the heritage smells discussed in the work, as follows:

VIAL NUMBER	CHAPTER	SMELL REFERENCE	AUTHOR
1	INHALING KNOWLEDGE	Old book extract	C. Bembibre
2	INHALING KNOWLEDGE	Historic Library interpretation	S. Mc Cartney
3	SMELLING THE PAST	Knole's pot-pourri	S. Nelson
4	VISIBLE & INVISIBLE	Black Bison Wax	Liberon
5	A MUSTY ODOUR	Mould smell - sample 1	T. Sawoszczuk
6	A MUSTY ODOUR	Mould smell - sample 2	T. Sawoszczuk
7	A MUSTY ODOUR	Mould smell - sample 3	T. Sawoszczuk

These scents are included for you to reference during the reading as necessary. With two exceptions (3 and 4, which are directly connected with the spaces and practices at Knole House), all scents were created during the research project and therefore would be otherwise unavailable to readers.

Smell and heritage

The significance of olfaction in the context of cultural heritage, evidencing that smells can be fundamental in shaping who we are, where we belong and how we experience encounters with different cultures, has been recently examined in several case studies. They show that odour can be part of the local identity through history (Boswell, 2008); that a central place for olfactory experiences in a culture results in a much wider vocabulary to discuss smells (Majid, 2015) and that travel and tourism offer an opportunity to approach the world with our noses (Pan and Ryan, 2009). However, the role of smells in our perception of and engagement with the past has not been systematically explored.

In the heritage context, experiencing what the world smelled like in the past enriches our knowledge of it, and, because of the unique relation between odours and memories, allows us to engage with our history in a more emotional way (R. Herz, Schankler and Beland, 2004) and can even make us “feel a part of what is being smelled” (Stevenson, 2014). The deliberate presence of an odour can also make us feel closer to exhibits and arouse negative emotions that might be appropriate as part of the collection, such as fear in an exhibition about war (Levent and Pascual-Leone, 2014). In the case of a gallery, the presence of point-of-scent components heightens the enjoyment of the public, in comparison to experiencing the same displays without smells (Bembibre, 2015).

Smells are also powerful cues to remember an exhibition, as demonstrated at the Jorvik Viking Centre in York, England, which offers an olfactory idea of what the world smelled like 1000 years ago. The sensory experience of seeing, hearing and smelling the Vikings has been drawing people for 15 years, reaching numbers of 800,000 visitors annually, although the seven smells that integrate the collection might have lost their initial central stage in the promotional materials. A study conducted among its visitors found that renewed exposure to the same smells present in the exhibition helped visitors remember information about the display (Aggleton and Waskett, 1999).

Odours are powerful triggers for emotions via the limbic system of the brain, which deals with emotions and memory (Van Toller, 1997; Krusemark *et al.*, 2013). They are an effective way to evoke recollections; certain aromas can even act as part of the common memory of a generation. For example, people born before 1930 tend to display positive association with nature scents, and the fragrance of Playdough triggers nostalgia in those born after 1960 (Hirsch, 1992). Scents can also influence behaviour: in shops, a pleasant scent positively impacts customers' attitude towards the store, the evaluation of products and intention to revisit the place (Doucé and Janssens, 2013). A British company claims that treating customers with the smell of male sweat made them 17% more likely to pay their bills than a control group (Classen, Howes and Synnott, 1994). Mood and cognitive function are also affected: although olfaction is one of the least considered senses in pedagogy, aromas can improve learning through their connections with memory, mood and productivity (Baines, 2009).

7.2 Smell in museums

While museums were once spaces where handling objects as a way of exploring them was encouraged, these practices changed in the 19th century with the increase in the size of collections and the number of visitors (and potential for damage to collections), and more sophisticated display techniques that allowed seeing objects well without touching them (Bacci, F. and Pavani, 2014).

Visual communication is dominant in the museum of today. However, we experience the world with all our senses; the benefits of a multisensory approach to the examination of historic objects and practices have been argued (Ouzman, 2001; Mark S. R. Jenner, 2011) and since the turn of the century many heritage institutions have been staging multisensory exhibits. The inclusion of smell in museums can be related to attracting more visitors, adding a 'dose of reality' to the displays, exploring the connections between olfaction and other senses and even claiming a space for perfume as an art form.

The connection between smell and museums has been reviewed in two main categories: spaces devoted to smells and smelling (including perfume, food and

wine museums and exhibitions that draw attention to olfaction) and those which include smell in a multimodal exhibit (Stevenson, 2014). Among the first ones, the Osmothèque in France is unique for housing not only an archive of perfumery materials (many of which are no longer in commercial use due to ecological, health and safety regulations or price) but also a number of heritage perfume reconstructions, both from historic texts, such as the Parfum Royal -a Roman perfume from the 1st century described by Pliny the Elder (Secundus and Secundus, 2016)- and from documented formulas, such as Napoleon Bonaparte's eau de Cologne (Le Guérer, 2010). Another case in this category was an exhibition opened in 2008 in the Reg Vardy gallery in Sunderland, where some of the 13 smells, created by collaborations between artists and scientists, were a bouquet of extinct flowers, the scent of Communism and the aroma of Cleopatra's hair.

The second category includes different approaches, many of which result in smell as a gateway to an immersive experience. 'What is wrong with reality?', wondered Matthew Tanner, curator of Maritime Technology at the Merseyside Maritime Museum in Liverpool. He believed too many museums offered a nostalgic approach that convey distorted information. As a result of the efforts to offer a real-life experience of the life of a boat, on the Edmund Gardner ship of this museum visitors can smell fresh bread in the galley and hot oil in the engine room. In a similar line, Entertainment Manager Laura Sinclair mentioned 'authenticity' as a justification for the inclusion of a scent smelling of urine in *SAW Alive*, a horror-themed ride at Thorpe Park. She said: "We want *SAW Alive* to be as authentic and terrifying as possible to make visitors feel as if they are living in a real-life horror film. To do this we need to really push the boundaries of what our guests experience from a sensory point of view" (2010).

In addition to engaging the visitors to rethink the past as an odorous place, smells in museums can be a way of relating to the world of the 'other'. In their work on presenting the country's history in the National Museum of Australia, Wehner and Sear (2010) sought to display works to encourage visitors to engage with subjective experiences. For example, one of their sensory stations included "the pungent smell of dried sea cucumber" alongside cooking tools of Trepang

fishermen.

Scenting a heritage space poses several curatorial challenges. Drobnick argues that there is a risk that audiences might feel manipulated when the identity of the smell is not clear (Drobnick, 2014). The use of synthesized scents in this context, as opposed to ‘authentic’ (as in related to a unique material source) is also questioned by this author. This is partly because, when olfactory artists are not signing the work, museums tend to rely on commercial fragrance providers to scent exhibitions. Their catalogues are rich in aromas related to food and daily activities (‘banana’, ‘aftershave’), and interpretation/conceptual ones, especially those related to history: ‘Egyptian mummy’ is described as ‘a musty, mysterious aroma with hints of incense. Ideal for creating an authentic ancient Egyptian experience’ and ‘burning witch’ as ‘the aroma of burning wood, flesh and dread to immerse your visitors’ (Aroma Prime, 2019).

In any case, it is clear from the above examples that historic smells are often those chosen to present to the public, be it to add realism to a display about the past (e.g. the smell of the Viking fish market), engage the imagination (e.g. the smell of Communism) or document a changing world (e.g. the scent of a threatened/extinct flower).

However popular they might be in a museum setting, an investigation of academic publications evidences that, in general, the smells of the past are not considered a rigorous enough field of study, and are instead relegated to commercial novelties, museum exhibits with popular appeal and children's publishing: “Smells, it seems, still fit uneasily into the world of serious scholarship” (M S R Jenner, 2011).

This information can be contextualised by the findings of historians, who identify the transition from the eighteenth century to the present as a progressive deodorisation of modern life, exemplified by the relocation of cemeteries to the outskirts of cities, the development of public health and the lowering of olfactory tolerance (Adler and Corbin, 2006).

Changes in public and private attitudes since the eighteenth century towards health and hygiene led to olfaction being relegated as a means to perceive the world, and cleanliness being associated with an absence of certain smells, like natural body odour (in an interesting counterpoint to the deodorisation phenomenon, however, Classen et al. (1994) note that artificial body odour, in the form of scented products and perfumes, is encouraged).

In this landscape of disinterest or disregard for historic smells, it is hardly surprising that there has not been a systematic approach to identifying and documenting those smells that might hold cultural value.

7.3 Historic odours and olfactory perception

The primary dimension for interpreting smells tends to be hedonic; that is, how the smell is perceived in terms of pleasantness (Herz, 2006). Many factors, as I have shown, affect smell perception, including familiarity (Engen, 1982), safety (Dalton *et al.*, 1997), and semantic labels (R S Herz, 2003).

A scented display in a museum presents the opportunity to engage through the past via the nose. But can we learn anything from these smells? Researchers say that not necessarily; the original context and function of the smell have changed, and our sensibility (value of pleasantness, tolerance, familiarity) as perceivers is probably different as well: we are unable to experience the smell in the same way. An example of the inability to experience a historical event or object in the present in the same way it was originally experienced is discussed by Smith (2007) in the context of reenactements of historic battles, where participants aim to get as close as possible to the sensory world of the original soldiers by washing less, wearing clothes of similar materials and holding weaponry of similar weight and feel, among other efforts. Smith argues that even then, the original experience is inaccessible; to do so he relies on the history of different perceptions such as noise or pain (Morris, 1993; Schwartz, 2011). A suggestion in which historical distance could be accessed is that the museum team can help the visitor interpret the scent, sharing information about the

function, source and practices around it to help make the experience more meaningful (Caro Verbeek, 2017).

Whether or not a smell is perceived as authentic in a heritage setting is important; sensory incongruence leads to negative behaviour (in previous findings, lack of interest in books shown by potential customers in a scented bookshop, Doucé *et al.*, 2013). This leads us to consider the relationship between the olfactory properties of a source and the perception of its smell. A comparison with colour, another intangible property of tangible objects, might be useful. Colour can be described as an attribute of an object, and different theories consider it objective (i.e. depending on the object), subjective (i.e. depending on the viewer), or relational, where colour is a property that involves both physical objects and those who experience them (Hatfield, 2012). Smells can be treated in a similar way: as an attribute of the object, independent of the nose which smells it, a perception completely dependent on the smeller, or a communication between source and receptor, where meaning is created. The perception of a smell as authentic is, then, the result of an interpretation process. Although useful in this specific example, the comparison between the perception of colour and odour is limited and subject to controversy (Kaeppler and Mueller, 2013), as I will discuss later in this work.

7.4 Smell and heritage guidelines

In addition to the intentional smells presented in museums and galleries, some heritage spaces have a distinct and usually incidental smell, a result of the interaction of the furniture, the collections and the controlled ventilation. An unusual event, such as the news of an upcoming refurbishment, and therefore a threat to the familiar smelly atmosphere, can be the trigger for visitors to come to the space to discuss the smell and ask for it to be preserved. An example of such a discussion took place around the New York library that suddenly stopped smelling of old books once the volumes were encased in glass cabinets after renovations (*CBC Radio*, 2017) or with visitors asking the Kelvin Grove Gallery

in Glasgow to keep its smell “somewhere between old stone and furniture polish” after planned major refurbishments (Smith, 2018).

These petitions are usually met with surprise, as there is currently no strategy in the UK for the protection or preservation of smells. In heritage guidelines, the association of certain odours with the identity of a place is noted. Currently, smells are viewed as an aspect of cultural significance, an overall measure of the value of a particular place to the public, as introduced by the widely adopted Burra Charter (ICOMOS, 1988). Aesthetic value contributes to cultural significance and includes “aspects of sensory perception for which criteria can and should be stated”, and, as an example, “the smells and sounds associated with the place and its use”. Smells also share a relation with other aspects of intangible cultural heritage, such as language, industries, and tourism (Hyojung, 2013).

According to the guidelines published by the Historic Buildings and Monuments Commission for England (formerly English Heritage), the smells of a place are considered of value because they affect our experience of it. For this reason, they should be taken into account when defining the character of a historic area (English Heritage, 2016).

The link with a place and its identity is not sufficient to encompass all kinds of smells. Odours on their own, such as historic perfumes, are not formally classified as heritage, in the way buildings are by international standards of conservation such as the Venice Charter (International Council on Monuments and Sites (ICOMOS), 1964). This was recognized by Henshaw (Henshaw, 2013), who studied the way smells are defined in the urban environment, by conducting guided ‘smellwalks’ around different European cities. She stated: “In the UK, we have something called listed building status, so that beautiful buildings are protected and we’re not allowed to redevelop them. But there aren’t those equivalents for beautiful sounds or beautiful smells”. The temporary nature of odours, as well as the absence of a standardised vocabulary to talk about them (an issue affecting most odours, not just historic ones), might be contributing factors to this state of affairs.

Specific smells can also be related to cultural practices, expressions and knowledge. As an example, the art of Asian perfumery is threatened by industrialization and may be in need of protection. The smells carry the information about how practices have evolved throughout history, the materials associated with them and the conditions in which smells were experienced (Jung, 2015). In this case, smells are associated with intangible practices, although they still emanate from a tangible source, as knowledge has no smell.

The odours of the Spice Market in Istanbul have recently been documented following the connections to local traditions and identity. The combined smells of the space, coming from fresh food, coffee, medicines, spices and perfumes (the 'smellscape') are disappearing due to multiple reasons, such as renovations that do not take the olfactory component into account or a reduction in green spaces. This project, carried out by a group of researchers from Koç University, looked to complement previous studies on the heritage of the site, which have been predominantly focused on the visual. Smells were identified and documented using a variety of techniques such as smellwalks, mapping, oral history interviews, and artistic performances (Davis and Thys-Şenocak, 2017).

Smellwalks have also been a starting point for the creation of 'smellmaps' of cities by McLean, a way to document many smells that have meaningful connections with a particular place or practice. Local participants in the walk identify smells at specific locations and record "description, expectation, intensity, personal association, and reaction". This data is analysed with the post-walk discussions, and a selection of it is used to create a map, an ephemeral smellscape of the city (McLean, 2017).

Also attempting to capture odours that might be forever lost was the project *Scent of the vanishing flora,* where Roman Kaiser and his team used headspace sampling technique and a porous polymer adsorbent matrix, followed by GC-MS analysis to sample and document the VOCs and aroma of endangered plant species (Kaiser, 2007). The significance of this project is not only the chemical documentation of plant qualities that will soon disappear, but to do so in relation

to the sensory experience they offer, as the team looks to sample and document “the scents emitted by living flowers/plants in a quality as perceived by the human nose”.

The interest in olfactory heritage is not limited to academia: several past and current businesses have focused on working with smells considered meaningful either for their connection with history or their ties to locality. For example, highlighting local heritage is one of the declared interests of a family-run company from Catalonia, Spain, which aims to 'capture the landscape' by collecting scented plants and distilling their smell, creating natural fragrances. In addition to the perfumes, the business offers walks around the region where participants can learn about and collect plants to distil their own fragrances. The locality of the project is stressed by detailing connections with regional essential oil producers, sustainable bee-keepers and ecological wine-making (*Bravanariz*, 2019).

In addition to individual efforts to identify and document smells with cultural value, there are a couple of examples where policies were made around olfactory heritage. A community-led selection of aromas recognized as heritage can be found in the Japanese Ministry for the Environment ‘100 most fragrant’ list, which was established in 2001 after a nationwide consultation where 5600 candidate smells were submitted by local groups. The aromas included ancient woods, sea breeze, sake distilleries and a street lined with bookshops. The 100 chosen aromas and their sources are now protected and carry a seal that reads “scents to be handed down to our children”. In addition to the recognition of significance as a cultural legacy, these smells are also an important element of regional promotion (Ministry for the Environment, 2001).

Representing the smell-related practices of a wide range of communities too is the recent inscription by The United Nations Educational, Scientific and Cultural Organization (UNESCO) of the region of Grasse (France) on the Representative List of the Intangible Cultural Heritage of Humanity (UNESCO, 2019). This is in relation to skills related to perfume, covering three aspects: the cultivation of perfume plants; the knowledge and processing of natural raw materials; and the art of perfume composition It recognises not only the technical skill but the artistic

aspect of perfume-making. This is an important precedent, as it is the first time an international organisation has recognised olfactory heritage.

7.5 Heritage smells: exploring a definition

In addition to the above-mentioned precedent, UNESCO discussions around intangible heritage can be a starting point for a definition of heritage smells. For the organisation, intangible cultural heritage are “practices, representations, expressions, knowledge, skills -as well as the instruments, objects, artefacts and cultural spaces associated therewith- that communities, groups and, in some cases, individuals recognize as part of their cultural heritage”. Identifying intangible heritage, discussants said, it was key “to conserve human creations that may disappear forever”, “to strengthen identity”, “to provide historical continuity in addressing the apparent psychological need for people to feel that they belong to some historical tradition' and 'to foster enjoyment”. Examples of this type of heritage were “languages, literature, music, drama, dance, mime, games, hunting, fishing and agricultural practices, religious ceremonies, traditional skills in weaving, building and carving, cuisine, extrajudicial methods of dispute resolution, traditional medicine and traditional knowledge applied to plants and their medical, biological and agricultural properties” (*Text of the Convention for the Safeguarding of the Intangible Cultural Heritage, General Conference of the United Nations Educational, Scientific and Cultural Organization (UNESCO)*, 2003).

In this context, heritage smells could be thought of as those smells resulting from a process of inventory among the population of a place (perhaps not necessarily or no longer linked to an existing geographical source) or one that could carry cultural significance for its associations with a historical source, practice or event.

As the place of smell in heritage has begun to be discussed, so has the observation that the dynamic nature of olfactory ‘objects’ does not fit well within the current definition of intangible heritage (Boswell, 2008; Drury and McPherson, 2008). This presents a specific set of challenges in current museum practice when smells are used as part of collection interpretation.

However, not every historic smell is a suitable candidate for analysis and preservation, because not all historic smells have heritage value. Therefore, the first step in the proposed framework involves the identification of heritage smells.

Some concepts from the current evaluation policies can be helpful to illustrate how the cultural value of a smell can begin to be considered for its designation as olfactory heritage. Associative characteristics, an important aspect the determination of cultural significance of Scottish historic monuments (Historic Scotland, 2011), are considered more subjective than intrinsic or contextual ones. They include “significance in the national consciousness or to people who use or have used the monument, or descendants of such people” and “the associations the monument has with historical, traditional or artistic characters or events”. In the context of this work, the associative aspect reflects the relevance of the provenance of a certain smell. It also encapsulates the importance of understanding the role of that smell in the public’s memory or collective imagination.

Out of the four sets of values identified by Historic England, there are two that can be relevant to assess the significance of a smell: historic value, both in its illustrative aspect, which “has the power to aid interpretation of the past through making connections with, and providing insights into, past communities and their activities through shared experience of a place” and its associative aspect: “association with a notable family, person, event, or movement gives historical value a particular resonance”. Communal value is also an assessment category that can be used to consider the cultural value of a smell. It derives “from the meanings of a place for the people who relate to it, or for whom it figures in their collective experience or memory” (Drury and McPherson, 2008). Finally, interpretive criteria, defined by the Heritage Collections Council of Australia as “the value or utility the object has for a museum as a focus for interpretive and educational programs […]” may also be significant for their links to particular collection themes, histories, or ways of seeing the collection (Heritage Collections Council, 2001).

7.6 Characterisation of smells

Since most odours are composed of volatiles organic compounds (VOCs) (Dincer, Odabasi and Muezzinoglu, 2006; Strlic *et al.*, 2009) the analytical methods frequently involve headspace solid phase microextraction (HS-SPME) and gas chromatography-mass spectrometry (GC-MS). However, it needs to be stressed that not all compounds that could trigger the sense of smell can be determined using this technique. For inorganic compounds, and some organic compounds that are difficult to sample using SPME, other sampling and analytical techniques may be more useful, from direct detection to various types of separation techniques (Patnaik, 2010).

SPME was developed in the 1990s by Pawliszyn et al. (Niri, Bragg and Pawliszyn, 2008; Pawliszyn, 2012) and is used for extracting volatiles in the headspace over liquid and solid samples. It is a technique based on adsorption; after being exposed to the sample, analytes can be thermally desorbed using GC. The fibre is available in a variety of adsorbent materials, and it behaves as a liquid solvent, selectively extracting analytes (Deibler, Acree and Lavin, 1999). It has been used successfully to extract and analyse VOCs from historic materials (Curran et al., 2014), including paper (Lattuati-Derieux, Bonnassies-Termes and Lavédrine, 2006; Clark et al., 2011). GC-MS techniques are routinely used to analyse perfumes and cosmetic preparations (Zhu, 2006).

SPME-GC-MS has been specifically optimized for analysis of the headspace of objects made of organic materials, such as book and paper (Strlic *et al.*, 2009), leather and parchment (Strlič, Kralj Cigić, *et al.*, 2009) and has been successfully used to sample air in libraries (Fenech *et al.*, 2010). Recent research shows that the profiles of volatile organic compounds found in historic libraries can be directly linked to the emissions from decaying books and wood furnishing (Fenech *et al.*, 2010), which makes it reasonable to assume that sampling VOCs both from books and from library environments can be done using the same technique, i.e. SPME GC-MS.

We smell in two ways: sniffing (orthonasal perception, inhaling from the nose) and retronasal smelling (odorants pass from the mouth to the nose via the back of the throat). Upon perception of certain chemicals via the receptors in the nose, the brain processess this information, relying on memory and trying to find a match for the olfactory stimulus. Previous exposition to the same smell makes identification easier, so experience is one of the factors that affects the way we perceive odours (Levent and Pascual-Leone, 2014).

The human nose is still the most sensitive detector for many compounds, and therefore instrumental techniques applied to odours have been developed where the human nose is used to detect smells, following a scientific method (Brattoli *et al.*, 2011). Gas chromatography-Olfactometry (GC-O) provides indicators of aroma that can be monitored by chemical analysis. The technique, which involves a modified GC with a sniffing port for the effluent, was first developed in 1964 by Fuller, Steltenkamp and Tisserand. The concentration of odorants can be correlated with its threshold to determine odour activity values (OAV), which indicates the potency of a specific odour-active compound in the sample. Furthermore, it has been shown that results from GC-O analysis approximate both the orthonasal and retro nasal experience.

GC-O been used to analyse scented consumer products (Bartsch, Uhde and Salthammer, 2016), food and beverages (Friedrich and Acree, 1998; Pet'ka, Leitner and Parameswaran, 2012), plants and wood (Helsper *et al.*, 2006; Schreiner, Bauer and Buettner, 2018). It is routinely used as an industry tool to identify odour nuisance (Kleeberg *et al.*, 2005) and even characterise illness-related VOCs (Panebianco *et al.*, 2017). In my review, no application was found for the technique to the analysis of historic odours.
Several sampling techniques can be used with GC-O; headspace (HS) analysis is fast when it utilises solid phase micro-extraction (SPME), thermal desorption, or direct injection (Mayol and Acree, 2009). It has to be noted that the identification of odour compounds remains a hard task even with GC-O/MS because some compounds co-elute with other analytes, and this makes the correlation between the detected smell and the VOC challenging (Brattoli *et al.*, 2013).

7.7 Description of smells

The vocabulary we use to describe smells is important and it is essential that a methodology to describe odours for archival purposes includes a sensory description, in addition to the chemical one. In some industries, the human nose is the main tool to characterise odours due to its accuracy and sensitivity (Gardner and Bartlett, 1994). Human olfactory experience depends on several factors, including genetic profile, ethnic background, gender, age (M.I., J.A. and D., 2013), cultural background (Ayabe-Kanamura *et al.*, 1998), and overall physical environment. The person's mood at the time of sampling can also have an impact on description of the hedonic tone (pleasant/unpleasant) of the smell (R. S. Herz, Schankler and Beland, 2004). Information on the evaluator and the evaluation circumstances can therefore be valuable metadata on the heritage smell.

The terminology to describe heritage smells is not standardised, in line with the general poverty of the olfactory vocabulary (Harper *et al.*, 1968; Van Toller, 1997). However, this is independent of our ability to perceive and identify different smells, and respond to them (Keller, 2014). Many attempts have been made to unify the way to describe odours pertaining to flavour, fragrances, or malodours (Harper *et al.*, 1968; Dravnieks, 1982; I H Suffet and Rosenfeld, 2007). Working with reports of odour nuisance, an odour wheel was developed based on descriptions by the complainants and cross-referenced it with potential odour-causing compounds (Curren, 2012). Recently, a bilingual (English-Spanish) dictionary for urban smells was created, using information from literature and urban smellwalks, and relating the selected terms to social media tagging (Quercia, D.; Schifanella, R.; Aiello, L.; Mclean, 2015). This latest experiment evidenced that, despite challenges posed by the ephemerality and invisibility of smells, techniques such as the 'nose-led' walks and crowdsourcing make the documenting of odours possible and even accessible. In terms of scientific analysis, efforts have been made to compile aroma compounds with their chromatographic and sensory properties (Acree and Arn, 2010). Recent studies also show that people with synaesthesia (a neurological phenomenon where a

stimuli directed to one sense leads to involuntary perceptual associations) perform better when identifying and naming odours (Speed and Majid, 2018) so this is an interesting direction in which olfactory vocabulary could be also explored.

7.8 Visualisation of smells

Smells are invisible and representing them visually poses a challenge. Whether the data related to odour comes from analytical chemistry techniques or sensory evaluation, the visual metaphors used to present it are very similar, and frequently draw parallels with other forms of perception, especially vision. For example, VOC sampling techniques are frequently compared to 'smell cameras' in the media and in research institutions dissemination channels (Agapakis, 2012; Kooser, 2013; Mohan, 2017). A focus not just on outreach but on academic papers reveals that hierachical methods of representation such as treemaps and wordclouds are often used in presenting sensory evaluation results, such as a summary of perfume descriptors (Lê and Worch, 2014; Zhou, Smith and Sharpee, 2018). Advantages of these techniques are offering a clear overview of the way the smell is perceived and, if colour is used consistently, allowing for easy data comparisons.

Figure 7-1. Wordcloud representation of Coco Mademoiselle (left) and Shalimar (right) perfumes based on comments. Source: *Analyzing Sensory Data with R* (Lê and Worch, 2014).

Novel methods of representing smells visually are being proposed, such as the 'ex-formation' (understood as "unlikely combination as suggestion") approach

recently suggested by artist Kate McLean, who used watercolour to translate smell data collected during walks around a city (Mclean, 2015).

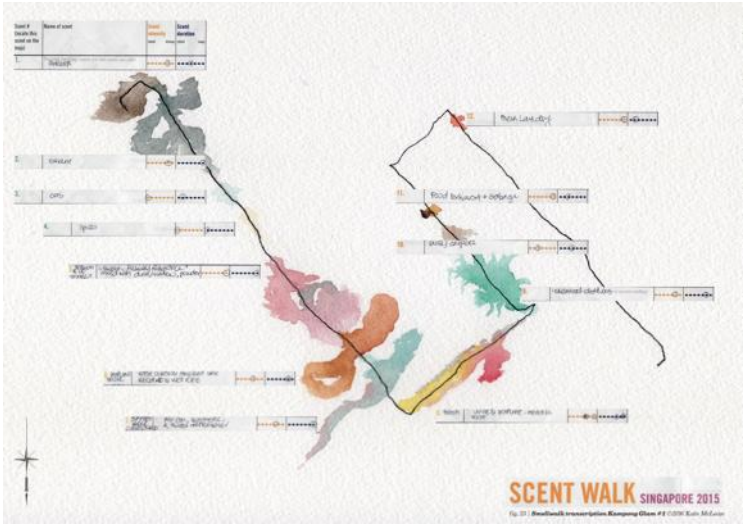


Figure 7-2. Smell data collected from a research project involving smellwalks represented using watercolours. Source: *Ex-formation as a method for mapping smellscapes* (Mclean, 2015). ©2016 Kate McLean.

Graphics depicting statistical analysis results, such as principal component analysis (PCA) are also occasionally used to communicate odour analysis findings (Zhu *et al.*, 2016). Spidercharts and odour wheels are among the most favoured tools to present odour analysis results in a holistic way (Fujioka *et al.*, 2009; Quercia, D.; Schifanella, R.; Aiello, L.; Mclean, 2015), although variations and limitations are significant.

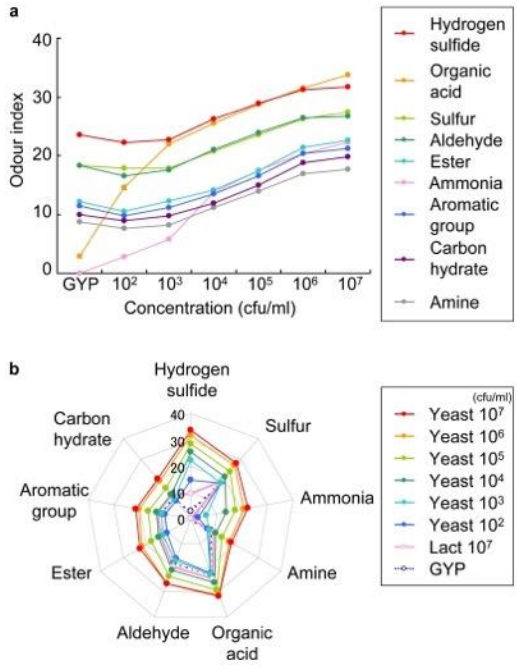


Figure 7-3. Graph and spiderchart showing values for odour analysis. Source: Combination of Real-Value Smell and Metaphor Expression Aids Yeast Detection (Fujioka *et al.*, 2009).

7.9 Proposed framework

All of the aspects considered in the Introduction could serve as a general framework to identify and document smells with historic value: (i) Significance Assessment; (ii) Chemical Analysis; (iii) Sensory Analysis; (iv) Archiving. Along with studies of the human experience of the odour, these aspects benefit the conservation, management and interpretation of cultural heritage, and are thus within the domain of heritage science as set out by the UK's Institute for Conservation (ICON) in 2006 (Mitchell, Lord, Paul, Lord, & Winston, 2006).

This opens up a new field of documentation and archiving (as well as conservation) of historic smells with heritage value, the foundations of which I explore in the four case studies that follow. Additionally, I propose the Historic Odour Wheel as a key documentation tool.

A graphic overview of this framework can be found, along with a discussion on its steps, in Apendix IV.

7.10 Chapter summary

- This overview in terms of historic odours and their cultural significance presents several opportunities to further explore the role of smells in heritage.

- Although role of odours in connection with emotions, personal experience and memory has been well-documented, the value of including smells as part of a heritage setting has not been formally investigated until now. In the chapters that follow I will explore this question and argue how the current state of things, in the context of our findings, creates an opportunity for heritage spaces to develop narratives and engagement with the public in connection with smells. I will also review current discussions around the nature of olfactory perception and its particularities, especially in comparison with visual perception, in connection with the concepts covered earlier in this chapter.

- I proposed a first definition heritage smells as those resulting from a process of inventory among the population of a place, not necessarily linked to an existing geographical source. Also smells that carry cultural significance for its associations with a historical source, practice or event.

- Historic or ‘lost’ smells are a kind that particularly speaks to public imagination, as we can see from the above examples. In these cases, matters of smell authenticity and approaches to odour reconstruction are especially relevant, and will be addressed both as discussions and in the experimental work.

- The perception and interpretation of smells depends on many factors, as evidenced in the discussion above. In the case of historic and heritage smells, questions of familiarity, safety and semantic labels become particularly interesting because the odours tend to be mediated by the museum interpretation and because we no longer share the sensibility of

the original perceivers of historic smells. An extended discussion on how considering these factors is extremely relevant for smells in heritage is presented later, in the context of a case study.

- Representing smells visually is a challenge; I have reviewed frequently used techniques and justified the choices for odour representation used in this work. In the next pages, I will engage in a more in-depth review of wheels for olfactory documentation, as no such tools have been developed for historic smells.

- There are many examples of museums using smells in connection to a display about past locations, events or practices; however, this interest has not translated into formal academic research into historic smells and into those aromas that might hold significance for their connection with heritage. The framework presented at the end of this chapter, validated through the following case studies, proposes a systematic approach to identifying, analysing and documenting these smells.

8 Inhaling knowledge. Characterisation of the smell of old books and study of authenticity of historic odours

The framework to identify, analyse and document smells with cultural value discussed in the previous chapter, Smell and heritage, required a case study to test its validity. The smell of old books was chosen because of its cultural significance, evidence of which will be provided later in this chapter. Prior studies on the VOC analysis of aging paper were also considered as a reference for the methodology and to contextualise findings.

When it comes to sensory experience, the connection between old books and historic libraries has been shown to be a close one, and the smell of both the object and the space (for the purpose of this study both smells will be treated together in terms of significance and characterisation) have been taken into account in previous documentation projects by artists, architects and perfumers (*Researchers bury their noses in old books at New York library to find its original scent*, 2017; Grossman, 2010). For this case study, St Paul's Cathedral Dean and Chapter Library, housed in a 18th-century chamber designed by Christopher Wren, was selected due to the distinct smell, often registered by visitors in the guest book: "City guide trainees we all loved the smell and beautiful library" (11/02/15); "Amazing place! I can inhale the knowledge" (09/03/15); "We can smell the history, the fragrance of heritage and our communion with souls of the past" (04/11/15).

Several questions needed to be addressed:

- How would people describe the smell when visiting the library and perceiving the scent along with several other sensory cues (the sight of the books and shelves, the sound of the pages being turned by the occasional researcher, the feel of the paper, leather, wood through their touch, if using the collection)? How would the smell be described and evaluated if all sensory cues were removed and no stimuli given?

- Could the sensory data be combined with the data from the VOC analysis?
- How could the authenticity of the smell, understood as ‘a culturally contingent quality associated with a heritage place, practice, or object that conveys cultural value’ (‘Nara + 20: On heritage practices, cultural values, and the concept of authenticity’, 2015) be accounted for?
- Could the smell be replicated for preservation purposes? Would the smell of old books and the library still evoke the memories out of context? Would that compromise its authenticity?

The framework led to the first two sets of questions: (i) research into the significance and (ii) the related VOC and sensory analysis that are presented in the first part of this chapter. Sensory evaluation was conducted both with a panel who visited the space and recorded their evaluation *in situ*, and with a larger study of untrained evaluators who characterised the smell as part of their visit to a museum exhibit that included scented displays. In order to explore the last set of questions, a third study was carried out, designed to investigate the question of olfactory authenticity in relation to perception of reconstructed odours.

The findings are therefore presented in two connected parts: the first one accounts for the analysis and documentation of the smell of old books and a historic library as a heritage smell, as well as its significance. The second part presents a study on the role of authenticity and interpretation in historic smell reconstruction and perception.

8.1 Historic book and library experiment results and discussion

Often, the smell of books intrigues and inspires: a copy of the novel *Ulysses* which belonged to T.E. Lawrence, filled with black smudges and holding biscuit crumbs between the pages, was documented as having “a sweet, somewhat smoky aroma that suffuses every bit of paper and leather” (Oram and Bishop, 2005). This embarked several researchers in a quest to find out the author’s life experiences behind the fragrant notes. Finding scientific analysis out of their possibilities, they had the smell evaluated by a group of conservators “whose

highly trained noses were so acute that they could detect the differences between strains of molds". Unfortunately, they did not agree in their descriptions, which ranged from pipe smoke to liquorice. The authors finally discovered that the smoky odour was most likely the result of the pages being exposed to tobacco for long periods of time. The source of the tobacco smoke, they identified, were the pipe-smoking soldiers stationed in the same military base as T.E. Lawrence, who borrowed books from the author and read to pass the time. In this case, association with a prominent author gave significance to the information resulting from the sensory analysis (it also highlights a challenge I will address later in this chapter, related to describing smells out of context).

Old books smell like "a combination of grassy notes with a tang of acids and a hint of vanilla over an underlying mustiness" (Strlic *et al.*, 2009). These aromas, along with those of the surrounding furnishings of a historic library space, create the unique smell that many visitors notice and comment on, conferring significance to this odour through its communal value. Similarly, users of archives consider smell as an important characteristic of documents; this could be related to the fact that, in the age of digitization, working with physical records is an increasingly rare practice, and therefore the opportunity to touch and smell the documents is perceived as valuable (Beentjes, 2013).

The original document always carries material evidence of its history, such as 19th-century letters smelling of vinegar, which was used to disinfect the paper to prevent the spread of cholera. In this case, the smell of the document served as metadata, often betraying the hopeful tone of the communication with evidence that the author was writing from a disease-stricken town (Duguid, P. and Seely Brown, 2000).

Further evidence of the significance of the smell of books in the collective olfactory memory is the number of scented products themed on books and libraries (over 30 candles, perfumes and oils) available from a single London store in 2015. Since these products present the smell of an object or a space out of its original context, they offer an interesting example on how much of the olfactory experience is modulated by non-olfactory factors, for example, the name

of the scent even if, in an informal sniffing session, not many of these scents were evocative of books or libraries. In order to understand evaluations for the smell of books out of context, I conducted a study (discussed in the sensory analysis section of this chapter) asking museum visitors to describe the smell presented without labels or other forms of the original context.

Nowadays, print books co-exist with e-readers and other screen-based options. As convenient as they may be, many readers long for the nostalgia that the smell of a book can evoke (Bilton, 2012), even if it is delivered as an 'air-care' product. It has been argued, however, that although evidence is lost when the texts are digitised, this process does not necessarily produce a copy of inferior value. Some materiality could be restored to digital copies by using existing technology to recreate historical smells as a way of evoking "particular states of historical consciousness" (Turkel, 2011).

While the smell of books is collectively appreciated, the records of its description are individual. For example: "Collected Papers on Museum Preparation and Installation of 1927 was described as 'armpit'; the 1967 American Folk Art in the Collection of the Newark Museum 'smells gross; dog poop', and the Civic Value of Museums evokes 'cigar smoke and tea'", wrote artist and librarian Rachael Morrison, as part of her project *Smelling the books*, where she recorded her evaluation of the smell of books from the library of the Museum of Modern Art (MoMa) in New York (Grossman, 2010).

The relevance for the smell of books and libraries as a case study is strengthened when the cultural significance is coupled with the research conducted on the volatile organic compounds (VOCs) constituting the aroma of historic books as a non-destructive diagnostic tool for paper degradation (Strlič *et al.*, 2007; Strlič, Thomas, *et al.*, 2009), addressed in the next section.

8.1.1 Chemical analysis

The goal of this experiment was to gain information on VOCs emitted by historic paper and compare it with the VOCs found in the environment of the library in St. Paul's Cathedral, London (Tab 9-1). While VOCs of historic paper have been

studied before (Lattuati-Derieux, Bonnassies-Termes and Lavédrine, 2006; Strlič *et al.*, 2007), it has been under different approaches, mostly concerning material change and therefore indication of degradation in books.

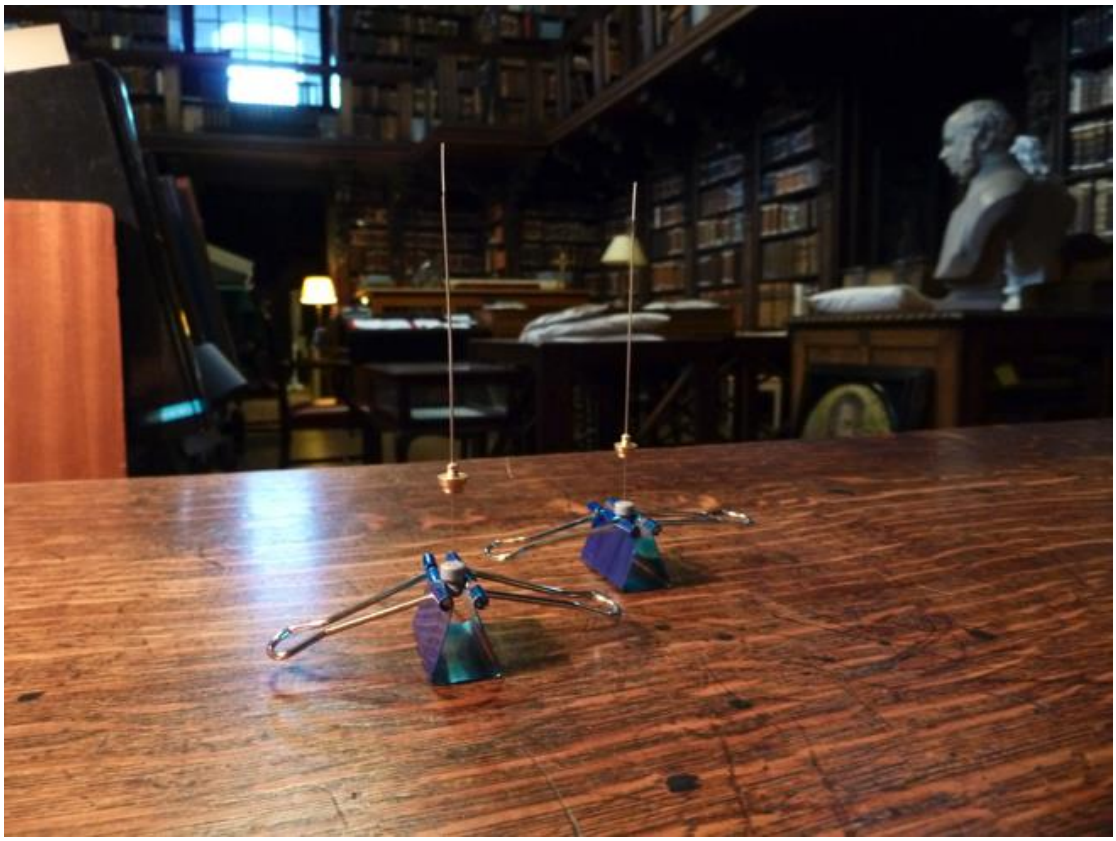


Figure 8-1.SPME fibres during sampling of VOCs at the library in St. Paul's Cathedral, London, UK. SPME fibres during sampling of VOCs at the library in St. Paul's Cathedral, London, UK.

A selection of the major VOC peaks found in the historic book and the historic library is presented in Tab 9-1. The criteria for selection was to include those compounds that 1) had been previously observed in naturally aged paper, and correspond to cellulose and lignin degradation products (Strlic *et al.*, 2009), 2) corresponded to volatiles with a smell known to be perceivable by the human nose (Acree, T and Arn, 2004; Mosciano, 2019) and 3) had a significant peak area (>300000 AU), which clearly separated it from possible noise. The results of analysis of the two samples (one from an historic book and one from the environment of a library, details in the methodology section) are presented in a single table since most of the compounds were present in both samples, so they were documented in conjunction, another reason why the smell of books and library as treated as one in this study. The degradation reactions are either

hydrolytic or oxidative and lead to the production of VOCs in varying proportions, depending on the composition of paper and its rate of degradation (Strlic *et al.*, 2009). The data in this table could, with further quantification, be used as a base to identify volatile compounds relevant to the smell and be potentially used to recreate it in the future by following the same 'formula' and may thus be of archival and ,conservation value.

RETENTION TIME (min)	CAS	COMPOUND	AROMA DESCRIPTOR	MASS PEAKS FOUND (m/z)
10.59	64-19-7	acetic acid	sour	47,48,60
13.85	79-09-04	propanoic acid	pungent, rancid, soy	74,73,57,55,56,46
17.46	2213-23-2	2,4-dimethylheptane	gasoline-like	85,57,71,56,84,70,55,69
17.67	108-88-3	toluene	paint	91,92,65,63,51,93
18.6	66-25-1	hexanal	grass, tallow, fat	56,57,55,72,82,67,58
20.23	111-84-2	hydrocarbon (possibly nonane)	alkane	57,56,55,85,70,71,69,84
21.23	98-01-1	furfural	bread, almond, sweet	96,95,67,97,50,51
22.15	111-71-7	heptanal	fat, citrus, rancid	70,55,57,81,71,96,68,86,56,72
24.04	n/a	hydrocarbon	alkane	57,71,85,55,84,70,56,69,113
25.47	n/a	hydrocarbon	alkane	57,71,85,70,84,55,56,69,113,127
26.27	100-52-7	benzaldehyde	almond, burnt sugar	77,106,105,51,50,78
26.52	138-86-3	d-limonene	lemon, orange	68,67,93,79,91,94,92,53,136,77
27	n/a	hydrocarbon with >10 carbons	alkane	57,71,85,55,70,84,56,69
28.99	124-19-6	nonanal	fat, citrus, green	57,56,55,71,70,69,85,98,68

Table 8-1. Odorous compounds of samples from a historic book in a Tedlar bag and a historic library obtained by SPME-GC-MS in our experiment. The aroma descriptors are from Flavornet and Perfume & Flavorist databases (Acree, T and Arn, 2004; Mosciano, 2019). Ten largest mass peaks or peaks above 100 found for each compound are listed in descending size order.

As is evident, the smell of historic books is a complex mixture of compounds. However, in order to interpret the chemical information, we need to explore the appropriate terminology and method to describe it.

8.1.2 Panel evaluation

The attribution of odour descriptors to the library environment is a way to contextualize the chemical findings. It can highlight the odorants most easily

perceived by the human nose in the sample but also potentially identify smells that were not extracted by the SPME fibre.

Regarding the sensory evaluation of the library, within the given list, ‘woody’ was the only descriptor of the list selected by 100% of the assessors, followed by ‘smoky’ (8 out of 9 people), ‘earthy’ (7 people) and ‘vanilla’ (4 people), as shown in Fig 9-2. The smell was also described as ‘musty’, “sweet’, ‘almond’ and ‘pungent’ by 2 of the panellists. Finally, the descriptors ‘medicinal’, “floral”, ‘fruity’, ‘green’, ‘rancid’, ‘bread’, ‘citrus’, ‘sour’ and ‘creamy’ were chosen by one of the participants each, whereas ‘chemical’, ‘paint’, ‘fatty’ and ‘minty’, which also corresponded to odorants found in the VOC analysis, were not considered relevant by any of the panellists (Fig 9-2). In the ‘other’ descriptor, the participants entered ‘enclosed’, ‘yellowish brown’, ‘historic’, ‘old books’, ‘distinct’, ‘chemical’ and ‘sharp’. As per the visual and verbal cue influence on odour classification, the relation of these findings to the non-olfactory cues (since the experiment was conducted in the library, participants could see wooden furniture, old books, etc.) and the verbal context of the given odour descriptors needs to be further explored.

Regarding intensity, the average intensity noted was 4.36, which sits in the scale between ‘strong odour’ (4) and ‘very strong odour’ (5), as shown in Fig 9-3.

Finally, the panellists rated their perceived pleasantness or unpleasantness (hedonic tone) of the library odour. On a scale that ranges from -4 (very unpleasant) to +4 (very pleasant), six of the assessors described the smell as ‘pleasant’, one rated it as ‘mildly pleasant’ and two as ‘neutral’ (as seen in Fig 9-3).

Figure 8-2. Odour quality descriptions from sensory evaluation by a panel of assessors (n=9). The evaluation was carried out in the library. Area size correlates with frequency of use of the descriptor during the study.

8.1.3 Sensory analysis

As noted, odour evaluation, and the emotional response to it, is affected by context (Morrot, Brochet and Dubourdieu, 2001). In order to test how a different environment affected the characterisation of the book odour, a study was conducted in the Birmingham Museum and Art Gallery, where visitors where presented with the (unlabelled and decontextualised) historic book smell, a total of 120 descriptors were collected from 79 respondents. A chart (Fig.9-4) was generated using hierarchical analysis, which presents more frequent terms in a larger area.

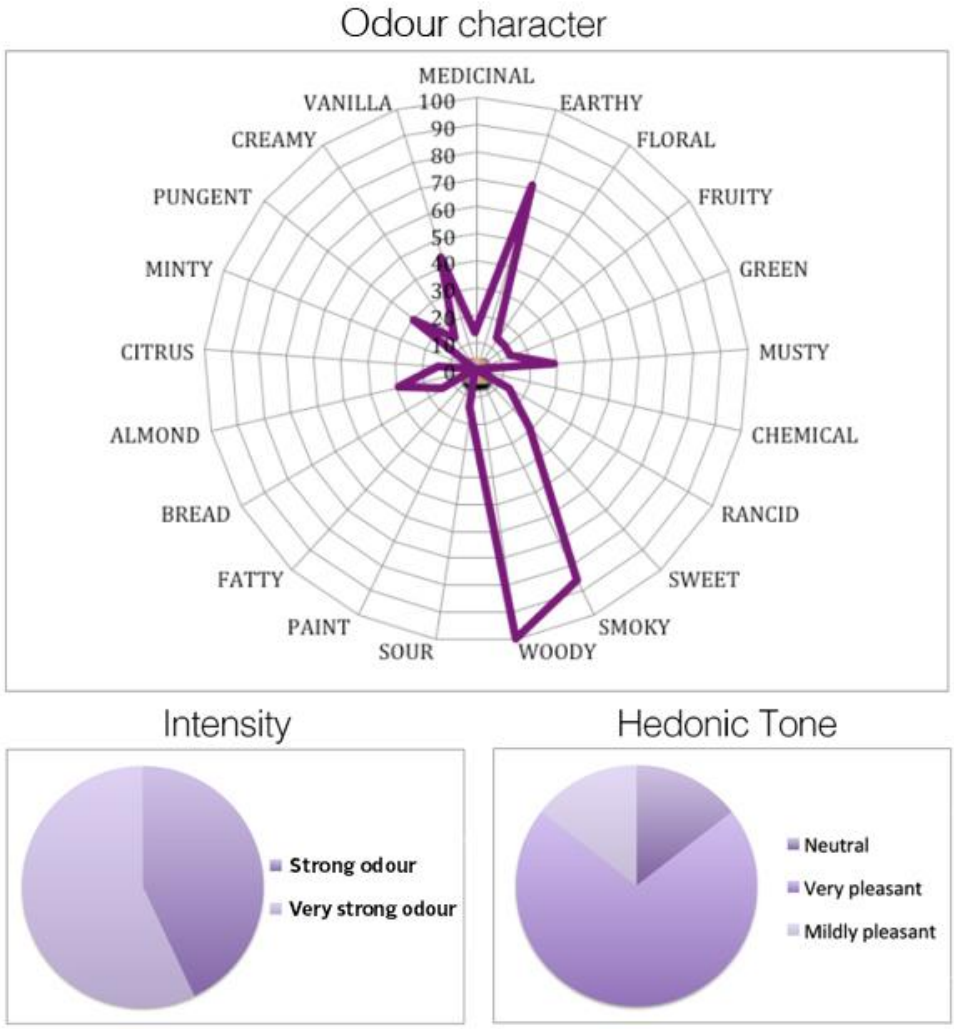


Figure 8-3. Results of sensory evaluation of the library at St Paul's Cathedral.

The word 'chocolate' was the most recurrent, with 29 mentions (with associated descriptors 'Cadbury' and 'cocoa'). It was followed by 'smoky' (20 mentions, with associated descriptors 'charred', 'burning', 'fire', 'bonfire', 'hot', 'burnt', 'ash', 'cinders' and 'coal'), 'coffee' (11), 'old' (8), 'wood' and 'vanilla' (both 5 mentions). Other descriptors were less frequent, as seen in the image with smaller areas.

Since the historic book smell was one of eight odours presented to the visitors during the exercise, it is possible that some of the descriptors for this smell were contaminated through sampling the other aromas, which included 'chocolate', 'coal fire', 'old inn', 'fish market', and 'dirty linen', coffee and HP sauce. It has been observed that providing linguistic or visual cues prior to odour sampling can affect the olfactory experience and influence smell classification (R S Herz,

2003). However, there is also evidence that in non-ambiguous smells (in the sense of odours only susceptible to verbal-context misperceptions within close approximation to their object category, such as ‘lime’ for ‘lemon’, which would be the case of the familiar scents of coffee and chocolate), the misperception triggered by the verbal context does not go beyond smells closely associated with the ones perceived (Herz and Clef, 2001).

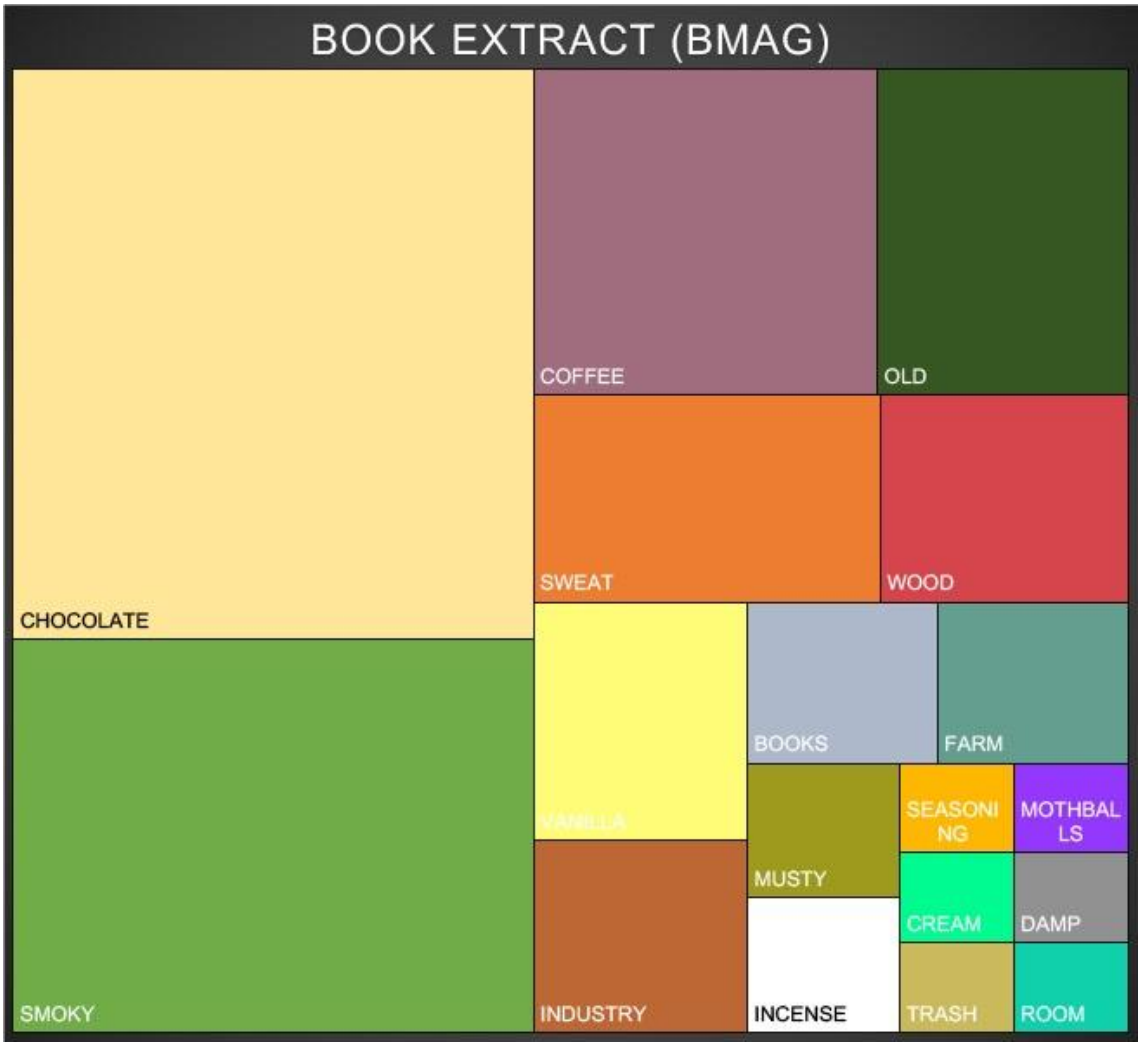


Figure 8-4. Odour quality descriptions from sensory evaluation by a panel of 109 museum visitors. Area size correlates with frequency of use of the descriptor during the study.

From the analytical perspective, and given that coffee and chocolate come from fermented/roasted natural lignin and cellulose-containing products, they share many VOCs with decaying paper. Cocoa as well as coffee are known to contain significant amounts of furfural and furanoid compounds, acetic acid, higher aldehydes (heptanal, hexanal, octanal), vanillin and benzoic acid, (Ducki *et al.*,

2008; Risticevic, Carasek and Pawliszyn, 2008), and many other compounds identical to those in decaying paper (Tab.9-1). It would therefore appear to be reasonable to expect for museum visitors to associate the aromas of chocolate and coffee with that of historic paper, considering that many volatiles in the aroma profiles of the three substances are identical and that, in addition, the same visitors were primed to think of chocolate and coffee while visiting the exhibition prior to responding to the questionnaire, because those two smells were available for the public to sample in some of the displays.

In addition to describing the smell, people tended to spontaneously comment on hedonic tone and intensity. This information can anchor sensory perception in a time and a place, which is important: once of the key considerations for historic smell preservation is that, even if the odour can be recreated to be identical to the original, the conditions of perception and the sensibility of those perceiving it cannot. For example, the description of a 'rancid' smell in a pre-refrigerated age might not necessary compare to what we consider 'rancid' today (Smith, 2014).

8.1.4 The historic book odour wheel

Combining the chemical and sensory analysis of a smell into an odour wheel to produce a holistic characterisation of it is an effective practice, widely used in the wine (Noble *et al.*, 1987), coffee (Spencer *et al.*, 2016) and perfume (Edwards, 2012a) industries, and similar tools have been developed and used successfully to characterise other types of smells. For example, wheels featuring odours, textures and colours present in patients' urine were used by physicians as a diagnostic tool in the 16th century (de Ketham, 1500). More contemporary, wheels feature urban smells (Quercia, D.; Schifanella, R.; Aiello, L.; Mclean, 2015), compost and drinking water and wastewater (I H Suffet and Rosenfeld, 2007) but, from my review, no odour wheels have been developed specifically for historic odours.

Although the odour wheel is a recognised industry documentation tool, there are several limitations to its use. Firstly, the methodology for creating aroma wheels is by no means standardised. I will present examples of this grouped in three

categories: (1) general wheels focused exclusively on sensory aspects, (2) general wheels combining sensory aspects with chemical information and (3) wheels focused on sensory aspects that record a personal experience or a personal understanding of smell descriptors. Examples of the first category are Noble's wine wheel, which classifies wine aroma hierarchically (a general category, e.g. 'chemical', a middle circle with subcategories, e.g. 'petroleum', 'sulfur', and a third ring, with specific descriptors such as 'tar' or 'garlic'). It has to be noted that the last circle of this wheel is open, inviting the addition of new descriptors. Overall, an effort has been made to group inner categories according to similarity (Lehrer, 2009). Edwards' wheel of fragrance also belongs in this group: it 'organizes fragrances by the dominant accord that give them their special character', comparing the methodology to 'the same ways that vineyards classify their vintages by grape varietal'; the tool also 'maps the connections among groups of scents' (Edwards, 2012b). Examples in the second category aim to establish a connection between the descriptors of odour character and the volatile organic compounds (VOCs) responsible for the smells, and, unlike the wheels in the first category, are the result of analysis that involves analytical chemistry techniques. For example, an odour wheel recording the smells of aged vinegar is based on odour activity value (OAV), a ratio which helps identify the contribution of different compounds to the aroma profile. The descriptors are correlated to chemical information obtained via SPME-GC-MS (Zhu *et al.*, 2016). Another example is the odour wheel of wastewater and drinking water, which is a tool to identify odour issues and the chemicals behind those odours (I H Suffet and Rosenfeld, 2007). The logic of this wheel is that the inner circle has "primary odour categories, similar to primary colours of the rainbow". The outer circle contains subgroups: 'grassy/woody' and is further deconstructed into 'grassy, woody, cardboard and hay' in the drinking water wheel. The outer ring contains chemicals associated with each sub-group. Many of these wheels are intended to be used with the untrained public, either to develop tasting vocabulary and expertise, choose a fragrance or identify odour nuisance. The wheels also have in common a visual uniformity that might mask the different approaches to building them.

Finally, the third category tends to contain examples that use the wheel as a documentation tool, with no intention of a practical application. An example of this is the wheel created as part of Rachael Morrison's project *Smelling the books*, which involved documenting her experience of sniffing volumes from the Museum of Modern Art (MoMA)'s library in New York (Grossman, 2010). This hand-drawn piece records the artist's personal impressions of the books' odour, in categories that range from the general ('flowers', 'wood') to autobiographical descriptions ('airport', 'wet bathing suit', 'under the couch'), adding evidence to how much of smell description is autobiographical. Also in this category we find artist Kate McLean's exploration of how smell vocabularies are shared between different classification systems: botany, perfumery, wine, neuroscience and urban design, with the added corpus of descriptors noted by people participating in a smellwalk, led by McLean in Pamplona, Spain. In this wheel, the outer ring presents different types of smell descriptors (such as odour source and geographic location), with a number of descriptors that don't fit into any category, subtly contributing to a wider discussion about the risks of perceiving odour wheels as complete tools, as we will see in the next paragraphs (McLean, 2016).

In addition to the diversity of methodologies behind the wheels, a debate about them is taking place among researchers in the context of visual representations of smells. Some warn about the risks inherent to the metaphor of a circle, which can be interpreted as completeness, discouraging future research: "The circle represents a universe – a whole. How do you cope with new molecules? And new olfactory notes? The history of perfumery shows that new notes have repeatedly been discovered for the world of perfumery. If you want to claim that the fragrance wheel represents a universe you have a hard time to look for new notes because they should be within the circle" (Noppeney, 2017). Others criticise non-explicit choices made during the wheel design, mainly related to slice size and arrangement, which can lead to inaccuracies in perception when using the tool: "Some slices are a lot wider than others. Why? Because they have a lot of specifics (the Wine Aroma Wheel "fruity" category has 19), while others have a few ("woody" has just 7). Assigning a large fraction of the wheel to "fruity" implies that it is a dominant odor category, and that "woody" is relatively subordinate. But from a sensory evaluation perspective, this is not necessarily true: a given wine

may display several fruity notes, but it's extremely unlikely that any wine will display all 19 fruity notes. Furthermore, even when several fruity notes are present, it doesn't mean that they dominant that wine's aroma. A Chardonnay's fruit notes may be overpowered by oakiness" (Avery, 2017).

Some of the stated limitations of the wheels are counteracted by many researchers' effort to conceive them as dynamic tools: they evolve when new information is gained about the causes of a particular smell (I H Suffet and Rosenfeld, 2007) and users are trained in implementing and contributing to that evolution (Mendrey, 2014). While wheels tend to be used in the context of sensory panels, there is evidence that trained and untrained assessors identify similar global differences in aroma perception (Veramendi, Herencia and Ares, 2013).

In this case, creating an odour wheel for historic smells, where untrained noses could identify an aroma from the description and gain information about the chemical causing the odour, establishes a novel method of heritage documentation.

For the historic paper odour wheel (Fig.9-5), categories present in Suffet and Rosenfeld's urban wheel were the starting point. Similar descriptors obtained from museum's visitors were grouped; for example, old room, musty and dampness were grouped under the main category earthy/musty/mouldy. When no existing categories from the urban wheel encompassed the descriptions, a new category was created.

With the main categories in the inner circle and the descriptors in the outer circle, the aroma wheel also features the likely chemical compound causing the smell. In this case, the data has been matched using the information provided by the descriptions from the panel, the categories from the urban aroma wheel and the data from the GC-MS analysis of the historic book, referenced by established odour description databases (Tab.9-1).

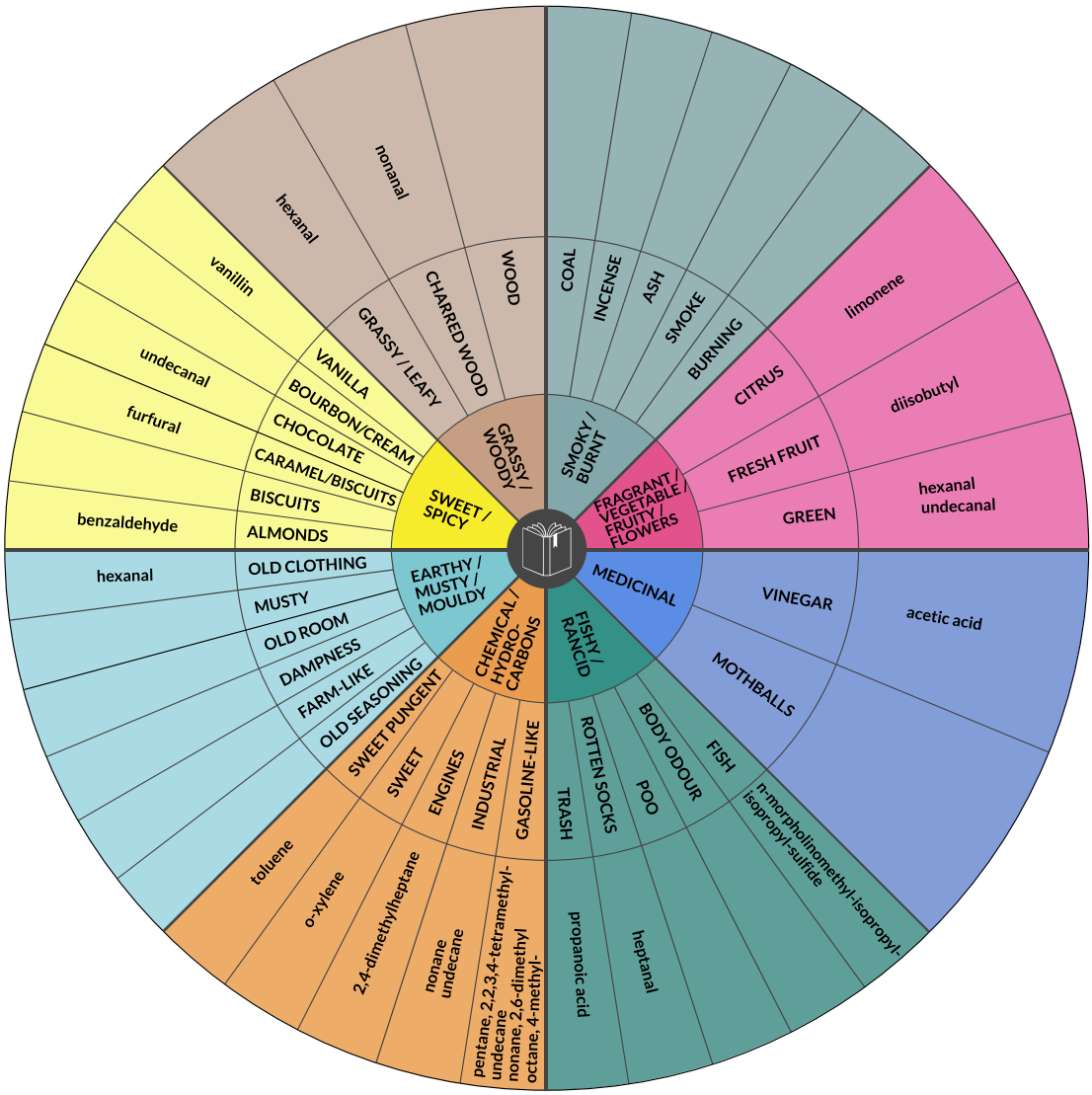


Figure 8-5. Odour wheel of historic book containing general aroma categories, sensory descriptors and chemical information on the smells as sampled (colours are arbitrary).

This historic book odour wheel is intended to be an interdisciplinary collaboration tool, used by untrained noses to 'translate' curatorial or conservational concerns about materials degradation into an understanding of the underlying chemical compounds causing it, and informing conservation decisions. The chemical aspects of paper aroma have been researched to a considerable extent in the past decade. It has been shown that some VOCs can be linked specifically to degradation of cellulose (e.g. furfural) and others specifically to degradation of lignin (e.g. benzaldehyde and vanillin), and that the VOC profile of a certain type of historic paper can be linked to its composition as well as to its state of degradation (Strlic *et al.*, 2009). While a thorough discussion of the associated degradation chemistry and material characterisation is outside the scope of the

work discussed here, it is worth pointing out that the perceived smell of a historic book could be of importance in artefact conservation and has been observed to be used by professionals in paper conservation practice.

Furthermore, it could help the interpretation of historic aromas, contributing to developing a common vocabulary to describe them.

8.2 Study of authenticity of historic smells

Authenticity is one of the central concerns of the study of cultural heritage, as expressed by the Nara Document, where the relative nature of authenticity is noted: “heritage properties must be considered and judged within the cultural contexts to which they belong” (ICOMOS International Secretariat, 1994). In this sense, the determination of authenticity requires an effort to integrate diverse cultural perspectives and recognise that communities have a key role in the identification of value within heritage. The new scope set out by the document in 2017 encompasses both tangible and intangible attributes of a property to be considered for conservation, reaching the definition of authenticity as “a culturally contingent quality associated with a heritage place, practice, or object that conveys cultural value; is recognized as a meaningful expression of an evolving cultural tradition; and/or evokes among individuals the social and emotional resonance of group identity” (‘Nara + 20: On heritage practices, cultural values, and the concept of authenticity’, 2015). It has been proposed that there are cases where heritage value can be affected without the authenticity being lost, as long as any changes (e.g. original parts replaced with reproductions) are acknowledged. Furthermore, it is possible in some rare cases to recover lost authenticity, where the statement of value highlights an unbroken period of cultural traditions (Boccardi, 2018). Additionally, to establish the authenticity of a heritage building there has to be a statement of value associated to it, which needs to be clear and precise and able to be verified by different types of evidence (Boccardi, 2018).

Tosic argues that a connection exists between the social factors involved in the evaluation and preservation of authenticity and “olfactory preservation, as the value which reflects and preserves the identity of the building, its function and its spirit”. In this context, an attempt at olfactory preservation needs to develop its own method of research and analysis, evaluation of authenticity sources, their relation to the implemented scent, as well as the concept of scents’ implementation. The most significant aspects of authenticity in the olfactory preservation practice, as presented by this author, are spirit of the place, design, form and function. Spirit of the place is associated with the building’s function, and the way smells are added through olfactory installations, or some other methods, such as cleaning (Tosic, 2017).

In the retail and marketing practice, odour, as sound and sight, is considered a key part of a brand because of the emotional response it can trigger and due to the measurable impact it can have on customer´s behaviour (Holland, Hendriks and Aarts, 2005). Olfactory design for a retail experience regards authenticity as “the feeling that something is appropriate, and not contrived” (Henshaw, V., McLean, K., Medway, D., Perkins, C., & Warnaby, 2017). To achieve this, it is recommended that the environment smells as it looks/does (for example, a chocolate shop smelling of chocolate), scents are chosen with cultural/geographical sensitivity (such as a Thai airline scenting the plane with jasmine and lemongrass) and product scents, even if artificially added, are consistent with the overall look/packaging, like a new car smelling of plastic and leather. Designers looking to scent a brand or a branded space need also to consider size, function, context, location and season. In certain cases, authenticity is the result of a process of odour management involving separation, deodorization and masking (Henshaw, V., McLean, K., Medway, D., Perkins, C., & Warnaby, 2017).

Advertising and branding experts also advice companies on the importance that their brand has the ‘right’ smell. In this context, authenticity seems to be the perception that the smell fits in with the brand’s purpose or the product’s function

and not necessarily provide a pleasant experience in itself. For example, Lindstrom reports sales of a floor cleaner with a traditionally 'potent' smell decreased almost 30% when its scent was changed to that of roses, presumably because the olfactory cue of the product being efficient, as recognised by its customers, had disappeared. In another example of how the perception of authenticity is not always obvious, a study revealed that the smell most customers associated with the coffee chain Starbucks was not that of roasted coffee but of sour milk (Lindstrom, 2010). The perception of authenticity of a smell appears closely related to the combination of the odour and non-olfactory factors: in a recent study where the smell of chocolate was diffused in a bookshop, customers were almost six times more likely to buy a romantic novel or a cookbook when the scent was present (a 40% increase in sales), as these books were perceived to be thematically congruent with the smell, but the scent had a negative impact on customers browsing or looking for books considered thematically incongruent with the smell, such as history or crime. These customers were negatively predisposed towards a purchase (Doucé and Janssens, 2013). So even when the books were not the source of the chocolate smell, it could be said that people perceived an authenticity in the sensory experience that led to their behaviour.

A smell can sometimes reinforce the perception of authenticity of a situation, even if the odour is not 'authentic' in itself. Lindstrom (2010) notes that the smell of a new car is valued as an authentic 'statement of newness' and there is a recognition that the car becomes another everyday object when that smell is replaced by that of the owner and their lifestyle such as coffee, dirty boots, etc, even if there was never a material association between the car itself and the new car scent, which is sprayed throughout the interior the vehicle as it leaves the production line.

This displacement of the authenticity from a property of the smell to a result of the interaction between smell and other factors led us to consider whether the authenticity of a heritage smell could be successfully constructed even if the smell was not 'authentic' (in the sense of a direct result from a heritage space, practice

or object). The following study explores the connection between authenticity and the scent reconstruction/creation process.

8.2.1 Two versions of the smell of books

Working with the smell of old books and historic libraries, a familiar and well-characterised smell as it has been shown above, 32 participants were given two versions of it: an artist's interpretation of the smell of St Paul's Cathedral Library created by perfumer Sarah McCartney, and a laboratory reconstruction of the smell achieved by solvent extraction of an old book's pages.

McCartney created the scent directly after visiting the space and inspired by it. She described the smell of the library as follows: "the aroma which presents itself as the doors open is warmer and gentler than the rest of the building. Instead of the grey, airy and faintly superior air of the soaring space, the library was an inviting, brown, woody, welcoming place of dense collected shared experience. It smelled of worn leather, chocolatey vanilla, smooth wood and tobacco. It smelled like the place its residents came to relax, drink their cocoa, smoke their pipes and settle down for a good night's study". She interpreted the smell of the library in her own composition: "from my memory of the experience, I started with vanillin - one of the compounds created by decomposing cellulose, old books - and worked outwards. I added black tea extract, made from fermented tea leaves. It has a dry musty woods aroma. I added tobacco absolute, made from tobacco leaves. There are two cedarwoods, Virginian which smells like pencils and Atlas which smells more like a wild animal, and an oakwood extract made from sherry barrels. I used frankincense and cocoa extract for the chocolate spice aroma I perceived. The second synthetic was Saffraleine, a leathery aroma that's quite sharp by itself, but in small quantities in a blend will feel softer. With the woods and tobacco it gave me the old armchair smell. Finally Karmawood, a synthetic molecule which can be overused in woody amber modern masculine fragrances but as a small percentage of the formula, brings a richness to the natural woods" (McCartney, 2019).

The old book extract was prepared in the UCL ISH laboratory, and involved submerging and agitating the pages of an aged book in a low-odour solvent to separate the odorants from the raw material (see methodology chapter for details).

The smells were labelled sample 1 (historic library interpretation) and 2 (old book extract); respondents could smell them as often as required. They were asked to fill in a questionnaire with their impressions of each smell and answer two questions comparing both, designed to gain insight into the perception of authenticity of a heritage smell (a sample questionnaire is included in Appendix II).

8.2.2 Results and discussion

The study had a total of 32 participants who evaluated samples 1 (historic library interpretation) and 2 (historic book extract) without any context or additional information as to the source or notes of the scents. They were asked seven identical questions for each smell (see Appendix II for a sample survey), evaluating their perception of the edibility, familiarity, safety and hedonic tone of the smell on a 7-point Likert scale. Two matrices were also included to explore participants' beliefs on the source of the smells. Finally, once they had completed individual evaluation sheets for each odour, a forced choice was presented to select the smell that most closely reminded them of old books and historic libraries (or both).

At the beginning of the questionnaire, participants were asked to describe each smell in their own words. Fig.9-6 below presents a summary of those descriptions.

For the library interpretation, the most frequently used descriptor was 'sweet' (17%, associated descriptors were 'icing sugar', 'candy mice'), followed by 'vanilla' (14%, associated descriptors 'cooking essence' and 'vanillin') and 'warm'

(9%, associated descriptors ‘hot’, ‘deep’, ‘bonfire’, ‘ash’). Other frequent descriptors were ‘strong’, both as a description of character and intensity (9%, associated descriptor was ‘powerful’), ‘woody’ (6%, with associated descriptor ‘oak’). ‘Vintage’ (with associated descriptor ‘old’) and ‘alcohol’, were both mentioned by 5% of participants.

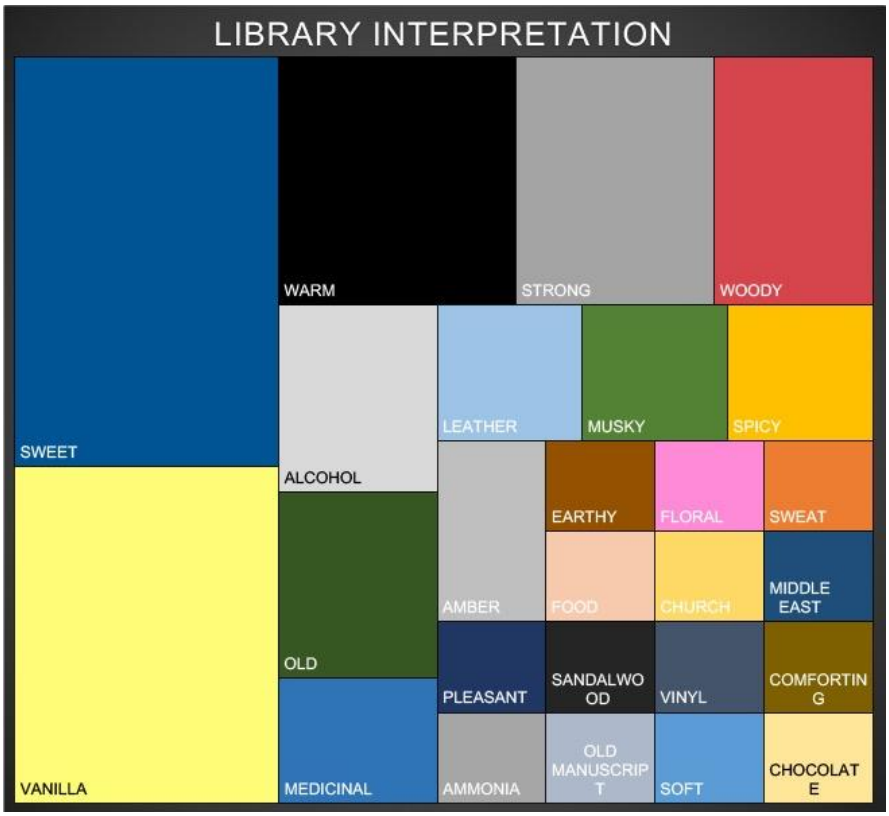


Figure 8-6. Odour quality descriptions for the historic library interpretation and old book extract from participants evaluation. Area size correlates with frequency of use of the descriptor during the study.

For the book extract, the most frequently used descriptor was ‘medicinal’ (14%, associated descriptors were ‘witch hazel’, ‘anaesthesia’, ‘medical’), followed by ‘plant’ (10%, associated descriptors ‘garden’, ‘vegetable sap’, ‘moss’ and hawthorn blossom’) and ‘sweet’ (10%). Other frequent descriptors were ‘gentle’, both as a description of character and intensity (8%, associated descriptors were ‘subtle’, ‘light’, ‘faint’) and ‘sharp’ (also 8%, with associated descriptors ‘acetone’, ‘vinegary’ and ‘cleaning fluid’). ‘Old’ and ‘fruity’ were both mentioned by 6% of participants, while ‘fresh’, ‘mould’, brandy’ and ‘musky’ were each mentioned by 4% of evaluators.

The ‘medicinal’ descriptor, common to both smells, frequently appears in association with ‘musty’ (Mosciano, 2019), which was a descriptors panellists of the BMAG study also used when describing the book extract. Because the book extracts were prepared for sensory experiments exclusively, VOC analysis was

not done. In view of the findings, a natural progression of this odour characterisation would be for future work to identify chemical similarities and differences.

In terms of evaluating edibility, the library interpretation was considered mostly ‘edible’, as mentioned by 45% of respondents, with 25% of participants reporting ‘I don’t know’. This is consistent with the descriptors used for this smell, 34% of were related to edibility (chocolate, food, sweet and vanilla) while the book extract was considered mostly ‘non-edible’ by 70% of respondents, with 15% of participants reporting ‘I don’t know’, also consistent with edibility-related descriptors accounting for 20% of the total (brandy, fruity and sweet). The difference in responses was not, however, statistically significant (p=0.198).

Figure 8-7. Edibility, familiarity, safety and hedonic tone ratings for the library interpretation and historic book extract (n=33).

When asked to rate their familiarity with the smells, evaluators found the library interpretation more familiar (27% reported that the smell was ‘very familiar’, 33% chose ‘familiar’ and 27% ‘moderately familiar’) than the book extract, which was considered ‘very familiar’ by only 3% of respondents, although 30% found it ‘familiar’ and 42% ‘moderately familiar’. While 3% of participants found the library

interpretation ‘moderately unfamiliar’, 12% of evaluators found the book extract ‘moderately unfamiliar’. Both smells were considered ‘unfamiliar’ by 3% of people surveyed. The difference between familiarity ratings for the library interpretation and the book extract were statistically significant (p=0.009).

Participants were asked to evaluate their perception of safety in relation to the smells. The library interpretation was overall considered a safer smell, with 37% of respondents evaluating it as ‘very safe’, and 26% considering it ‘safe’ and ‘moderately safe’. Only 11% of participants thought the smell was ‘moderately dangerous’. This is consistent with the edibility evaluation, as odours considered from an edible source are also evaluated as less dangerous (De Wijk and Cain, 1994). In contrast, only 8% of evaluators considered the book extract as ‘very safe’, although 40% described the smell as ‘safe’ and 12% as ‘moderately safe’. This odour was considered ‘moderately dangerous’ by 16% of respondents, and ‘dangerous’ by 4%. Overall, 20% of participants rated the book extract as ‘neutral’ on the safety scale. The difference between safety perception for both odours was statistically significant (p=0.013).

The perception of pleasantness or unpleasantness (hedonic tone) is an integral aspect of odour evaluation. In this case, the library interpretation was overall considered more pleasant than the book extract, although both odours were rated mostly pleasant. Ratings for the library interpretation were 33% for ‘very pleasant’, ‘42% for ‘pleasant’ and 6% for moderately pleasant’ (81% of positive hedonic tone rating in total), while the book extract was considered ‘very pleasant’ by 13%, ‘pleasant’ by 34% and ‘moderately pleasant’ by 16% (63% of positive hedonic tone rating in total). The odours were negatively rated as ‘moderately unpleasant’ (9% for the library interpretation and 19% for the book extract) and ‘unpleasant’ (6% for both smells). Finally, the library interpretation was rated as ‘neutral’ by 3% of evaluators, while 13% thought the book extract was a neutral smell in terms of hedonic tone. The difference between the overall hedonic tone ratings was found to be statistically significant (p=0.019).

Human identification of odours is reportedly poor: adults have been shown to be able to identify around 50% of common odours when there is no context or

reference (Cain, 1979). In order to understand how much of the significance of the smell of books and libraries was related to the object and space, participants were asked to report their beliefs on the potential source of the odours, rating a 7-point scale for seven objects and seven locations. The results were analysed using the Dempster-Shafer theory, a framework for combining evidence and dealing with uncertainty (Orr, 2018), which has been applied to improve odour source location by robots (Ji-Gong *et al.*, 2015). (see methodology section for more details).

Potential source	Very likely		Likely		Moderately likely		Neutral		Moderately unlikely		Unlikely		Very unlikely	
A piece of clothing	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.34	0.87	0.65	0.03	0.00	0.00	0.00
A cleaning product	0.00	0.00	0.00	0.00	0.00	0.92	0.01	0.08	0.62	0.00	0.37	0.00	0.00	0.00
A vehicle	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.81	0.68	0.05	0.31	0.00	0.00
A book	0.00	0.00	0.00	0.00	0.01	0.00	0.86	0.31	0.12	0.66	0.00	0.03	0.00	0.00
A cosmetic product	0.00	0.00	0.00	0.00	0.24	0.72	0.75	0.28	0.01	0.00	0.00	0.00	0.00	0.00
A building material	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.45	0.68	0.54	0.01	0.00
Rubbish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.46	0.68	0.53	0.29

	Very likely		Likely		Moderately likely		Neutral		Moderately unlikely		Unlikely		Very unlikely	
A home	0.00	0.00	0.22	0.00	0.78	0.76	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00
An office	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.10	0.82	0.87	0.04	0.02	0.00	0.00
A park	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.46	0.53	0.53	0.46	0.00	0.00
A library	0.00	0.00	0.00	0.00	0.13	0.01	0.83	0.90	0.04	0.09	0.00	0.00	0.00	0.00
A theatre	0.00	0.00	0.00	0.00	0.01	0.00	0.89	0.27	0.09	0.73	0.00	0.00	0.00	0.00
A train	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.45	0.71	0.55	0.00	0.00
A coffee shop	0.00	0.00	0.00	0.00	0.01	0.00	0.86	0.00	0.13	0.32	0.00	0.67	0.00	0.01

Colour key
Historic Library Interpretation
Historic Book Extract

Table 8-2. Degree of belief associated with the source for the smell of the library interpretation. Darker shades show that a higher number of respondents shared the belief.

When asked to rate their degree of belief about several objects being the source of the library interpretation smell, 24% of respondents thought the odour was ‘moderately likely’ to come from a cosmetic product. Beliefs were stronger for the objects that were not likely to be the source, such as a piece of clothing (87% thought it ‘moderately unlikely’), a vehicle (81% thought it ‘moderately unlikely’), and a cleaning product (62% thought it ‘moderately unlikely’ and 37% ‘unlikely’) and a building material (31% thought it ‘moderately unlikely’ and 68% ‘unlikely’). Combined degrees of belief show that rubbish was thought not to be the source (46% thought it ‘unlikely’ and 53% ‘very unlikely’). 86% of people chose ‘neutral’

in relation to a book being the source of the smell, and 75% did so for a cleaning product.

In terms of environments that could be the source of the smell, 22% thought a home was ‘likely’ and 78% ‘moderately likely’, making this the most favoured option. A library was chosen by 13% of participants as a source, combined with 83% who selected ‘neutral’ for this environment. A theatre (89%) and a coffee shop (86%) also were highly selected to have a ‘neutral’ association with the odour. Locations that were believed to have a negative association with the smell were an office (82% thought it ‘moderately unlikely’), a train (71% thought it ‘unlikely’), and a park (53% thought it ‘unlikely’ and 46% ‘moderately unlikely’).

Regarding object as sources for the book extract smell, 92% of participants believed a cleaning product was ‘moderately likely’, and 72% thought the same for a cosmetic product (with 28% choosing a neutral association between the smell and this latter option). Neutral associations were also chosen for a piece of clothing (34%) and a book (31%). Objects negatively associated as a source for the smell were a vehicle (68% thought it ‘moderately unlikely’) and rubbish (68% thought it ‘unlikely’ and 29% ‘very unlikely’), a book (66% chose ‘moderately unlikely’) and a piece of clothing (65% thought it ‘moderately unlikely’).

In terms of environments that could be the source of the smell, 76% thought a home was ‘moderately likely’, while 90% though a library had a ‘neutral’ association with the smell. Also ‘moderately unlikely’ associations were significantly chosen for an office (87%) and a theatre (73%), while ‘unlikely’ associations were selected for a coffee shop (67%), a train (55%) and a park (46%).

Finally, after completing both sample smell evaluations individually, participants were asked to compare the historic library interpretation smell with the old book extract smell and answer the following questions through a forced choice option: *Now compare the smells. Which of these smells reminds you of old books? Which of these smells reminds you of a historic library?* (options were sample A, B or both).

In response to the first question, 45% of people thought the historic library interpretation was more reminiscent of old books, and 45% of participants thought the book extract was more reminiscent of old books, while 10% agreed that both smells reminded them of old books. Respondents to the 'both' option could either be reinforcing the similarity in memories that these smell arise or the diversity of smells of old book that people have experienced and recognise.

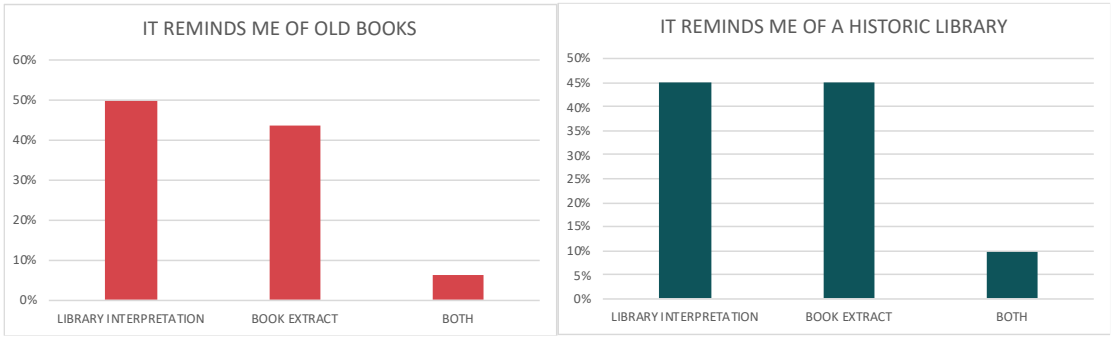


Figure 8-8. Comparison of how the library interpretation and the book extract smells (or both) reminded participants of old books and a historic library.

With regards to the smell that reminded them of a historic library, 50% selected the library interpretation, 44% the book extract and 6% both. Differences in responses to these questions were not found, as expected, to be statistically significant (p=0.64).

When answering these questions, respondents were asked to elaborate the reasons for their choices (as previously, sample 1=historic library interpretation and sample 2=old book extract). These are some of the comments:

- "Sample 2 has a musty scent and smells old, reminds me of a museum/old things. Sample 1 has a strong resemblance for me to icing sugar/vanilla essence, which I do not associate with historic library smell".
- "Sample 1 is too strong, smells like perfume but also like a clean place such as a lab (anosmia?). Sample 2 is like a still space, less strong, reminds of something old (but not rotten)".
- "Sample 1 has a leathery, musty scent. It smells like thumbed, warm, loved leather".
- "Sample 2 is deep, rich, textured and enveloping. Which is the effect I would hope to get from an old book or historic library".

- “Sample 1 and an old, deep heart. It smells cosy. Comfortable”.
- “Sample 2 is not as powerful as 1. Has a gentleness that sample 1 doesn't. Smells familiar to me, like my old university library. A hint of something I can't put my finger on! As above, there is familiarity in it. Books have a soft scent… I find sample 1 very powerful to begin with. I had to leave the tip off the bottle for a bit to be able to smell it without it being too overpowering and then found it pleasant. Sample 1 smells a bit 'chemical-ly' if that makes sense?”.
- “Sample 1 is warm, less clinical, has a smell of age/does not smell as synthetic as Sample 2”.

This study found an artist’s interpretation being rated as efficient in evoking the smell of old books as the lab-produced book extract. The historic library interpretation was considered slightly better at evoking the scent of a historic library. An implication of that is that olfactory authenticity construction and perception in a heritage context is a complex process that goes beyond the presentation of a smell with material relation to the source (in this case, the lab-produced scent was extracted from the actual book via a solvent). These are encouraging results in regards to possibilities for collaboration between scientists and artists in the creation of olfactory meaning as part of the heritage experience.

These findings are of interest to museum and gallery curators, collection managers and visitor’s experience practitioners, as well as architects doing olfactory preservation, and merit further investigation and testing of other heritage smells of different degrees of familiarity and under different narratives.

Some other results of this study merit discussion:

A comparison between the characterisation of the book extract in the study at the museum (discussed in the section on sensory analysis in this Chapter) and the one done on this study reveals the important role of context and other sensory and non-sensory cues in odour evaluation. Regarding the book extract, the panel evaluation in the museum, which assessed an unlabelled old book extract in the context of an exhibition featuring other smells, described it as more edible and more pleasant than the panel which evaluated the smell blindly. There were some

secondary descriptors in common (woody, smoky, the discussed association between medicinal and musty) but overall the characterisation was quite different. It has to be noted that the second historic book extract, evaluated either in lab conditions or at home, was done so in comparison with another smell (the historic library), which was rated more edible, so that might have had an impact. Given that both smells were created from the same source (the same historic book) using the same method (solvent extraction, albeit a different solvent, see methodology section for details), a possible explanation for this difference in evaluation is the role of context (sensory and non-sensory input at the time the smell was presented).

The library smell and the perfumer's interpretation of it had three of the main five descriptors in common (woody, earthy and vanilla) and some secondary descriptors were common to both, too: sweet, floral, medicinal and old. Although one was an incidental smell resulting from the library environment, and the description was produced in sight of the library space and the other a deliberate scent, described blindly, there were similarities in the use of descriptors by two different panels.

Positive associations of these smells in terms of source were not accurate in relation to the actual sources, which were in both cases revealed to have mostly neutral associations (with the exception of the book extract and the book, which were mostly moderately negative). This is consistent with previous findings reporting difficulties in odour identification when no context or other reference factors are provided for a smell (Cain, 1979).

Sample 1 and 2 only shared five descriptors, approximately between 25% and 35% of the total. Evaluation of their familiarity, safety and hedonic tone were significantly different. However, both smells were found to equally remind participants of old books, and very similarly of a historic library. Further exploration of how two very differently perceived smells can result in very close result in a forced choice question is needed.

8.3 Chapter summary

- The smell of old books has been shown to have cultural significance to readers, library and archive visitors and artists, among others. There is evidence that it is an integral part of historic libraries, contributing to their identity. In heritage practice, VOCs emitting from historic objects are often seen as indicators of the material condition, or as an undesirable result of storage conditions and used to make conservation decisions. These findings propose a third approach, where smells can be evaluated for significance as immaterial evidence of an object or space's history before a decision to intervene on them is made. In conservation, this could translate into facilitating the development of considerations about practices such as object cleaning, documenting and preserving odours, as well as taking significance into account when evaluating the effect of VOCs on materials, objects and collections.
- For this smell, the manner the odour quality is described as highly dependent on non-olfactory factors such as spatial context, visual cues and expectations of the perceiver, as evidenced by the difference in descriptors and valuation of edibility when the odour is experienced in the library, the museum or in laboratory conditions. The role of the language used to describe smells is significant, as the lack of a standardised vocabulary, coupled with the absence of olfactory education in the general public, make comparability of perception quite difficult.
- The data obtained during the analysis was successfully combined in an odour wheel; this can be a valuable and practical tool, as long as (a) its limitations are considered and (b) it is presented as a work in progress, open to improvement and development. In addition to the odour wheels, a wealth of metadata that reflects personal accounts of the smell significance needs to be taken account towards archiving smells.
- Authenticity is an important concept in smell perception because it helps process and interpret sensory information. It has been shown to be the result of an interpretation process, mediated by olfactory and non-olfactory factors, and should be one of the considerations for the use of odours as

part of the narrative of collections in heritage spaces. In my experiment, assessors were evenly split in considering that the extract and the interpretations reminded them of old books and historic libraries, although these smells were evaluated as significantly different for hedonic tone, safety and familiarity. The data, therefore, supports the collaboration between scientists and artists in historic smell interpretation.

- The findings of this case study are of interest to museum and gallery curators, collection managers and visitor's experience practitioners, as well as architects doing olfactory preservation, and merit further investigation and testing of other heritage smells of different degrees of familiarity and under different narratives.

9 Smelling the past. Odour preservation and characterisation of Knole's historic pot-pourri

Bringing a smell from the past in a museum, gallery of historic house is, as shown in the chapter Smell and heritage, a strategy followed to encourage visitors to experience the atmosphere of a different time or place. A bowl of pot-pourri placed among the displays, for example, can be an invitation to immerse oneself in the perfumed rooms of a 18th-century English country house. It can also be a way of learning about practices related to the smell, such as the creation of this home aromatiser, and the knowledge associated with its ingredients and preparation. In this chapter, I present a characterisation of this historic pot-pourri, as part of my investigation about the recreation of smells with cultural significance. The context that gives this odour its significance will be introduced, and the perception of this historic smell by contemporary noses -and sensibilities- will be discussed, highlighting their relevance to heritage.

The documentation and preservation of smells have historically faced a double challenge: on one side, the denigration of the sense of smell as a tool to understand and engage with the environment, in comparison to other senses, as has been previously discussed. On the other, the constraints of the technical aspects of odour recording and the challenges we have to describe and document smells (Henshaw, 2013). Odours in the built environment are no exception to these limitations. The interest in them has mostly been negative, following the approach cemented in the 17th and 18th centuries, when senses were divided into 'noble' (sight, hearing) and 'lesser' (smell, touch, taste) (Henshaw, 2013). The latter were understood to be an expression of the animal nature, and therefore uncivilised. Therefore, the emphasis on cities as sources of smells has been on the unpleasant and unhealthy, where "animals, humans, waste and industrial pollutants combine into the noxious smogs experienced both by previous generations in the west, and still in the megacities of the global south. As a result, olfaction has been tarred as having little positive to contribute to the city or architecture" (Henshaw, 2014).

Architect Marc Crunelle (Crunelle, 2002) identifies several reasons for the lack of focus on smell in architectural practice, including the fact that, even when odours are considered to be part of the environment, they are notoriously difficult to be accounted for because “we live in a hyper-visual world, we lack the tools, the means of representation for all these elements”. The enveloping nature of smells, which makes it impossible to establish a distance from them, is mentioned as an added complication. To account for the lack of odour mentions in historic architectural texts, Crunelle proposes that odours in the city might not be noticed due to olfactory fatigue (the temporary, normal inability to distinguish a particular smell after a prolonged exposure). A sense of unease about talking about pleasure (and odours as a source of sensory enjoyment) is another reason he highlights, as well as the lack of insight into the ‘olfactory practices’ of history, those botanical, medical or domestic activities that were intimately connected with an olfactory component, such as planting sweet-smelling flowers on high-traffic grounds, burning aromatic herbs to fight disease or using fragrant plants as an insect deterrent.

In terms of the technology to document and preserve smells, well-established techniques related to air pollution and odour management, such as the use of field olfactometers (instruments that measure odour dilution and odour detection threshold) to investigate malodour complaints, are now complemented by practices which focus on collecting odours from the smellscape, understanding it as the totality of the olfactory landscape and therefore including both episodic (fore-grounded or time limited) and involuntary (background) odours (Henshaw, 2013). These practices are, for example, sensory walks, or smellwalks, which can be a useful mapping and educational tool, and can also be a data collection technique; smellmaps of cities created on the basis of social-media data (Quercia, D.; Schifanella, R.; Aiello, L.; Mclean, 2015) or crowd-sourcing applications to report odour complaints, such as OdourCollect, which builds odour maps based on crowd-sourced odour reports to calculate frequencies and levels of nuisance (Odourcollect, 2019).

In addition to the increasing attention on the connection between the built environment and odour, and the advances in documentation of urban smells, the

matter of olfactory preservation has been central to recent discussions in architectural research. The value of odours and the capacity to create a sense of place and evoke memories is recognized in the context of historic buildings, with academics, perfumers and companies exploring the identification, documentation and reconstruction of smells related to the history of a space.

Central to these discussions are the critical use of smells, the possibility to use up to date knowledge to reread historical debates about the authenticity of buildings and the language used to talk about historic smells (Adam Jasper and Jorge Otero-Pailos, 2017).

The Arts Club building in Mayfair, London, presents an example where the scent of this members club, a space that hosted many social exchanges among personalities of culture, sports and entertainment, has been approached by deconstructing each element to create an olfactory atmosphere. The resulting fragrance, by olfactory design company Design in Scent, “evokes the scent of old manuscripts mingled with cigar smoke, fine leather and precious woods, and is lifted and feminised with chamomile and mimosa” (DesignInScents, 2019). The olfactory spirit of the old club (the building was refurbished in 2012) wafts today via a scent diffusion system in the air conditioning system. The environmental smell is enhanced by scented candles and reed diffusers with the same smell, and textiles in rooms are sprayed with the scent before they are presented to customers.

Gemma Hopkins, responsible for the reconstruction, has also worked on projects where the scent to be preserved is not from a space but from an object, such as the smell of a new mobile phone. She considers that “all the different layers that make up a smell” need to be taken into account when creating this type of scent. “From the notes in the background from the larger surroundings, e.g. oceanic notes if near an ocean, smog if in an industrial city, polished wood if inside a country house, to the notes that will be louder because they’re more in the foreground of the place or object you’re capturing. It’s really important to set a historic scent as firmly in its context as possible so it’s more realistic to the whole” (Hopkins, 2019).

Another example of olfactory reconstruction is the Philip Johnson's Glass House. The reconstruction focuses on the smells of the building between 1949 and 1969, and the starting point was an absence of public accounts of the house odour, or of its management (ventilation, cleaning, perfuming). The task of recreating the scent was carried out by architect Jorge Otero-Pailos in collaboration with perfumer Rosendo Mateu. Two decades of history in the house (1949-69) are evoked via three fragrances, designed to be smelled in sequence. Firstly, the smell of a new house, “a blend of newly lacquered wood closets, newly painted steel, fresh plaster from the ceiling, cement mortar from the floor and a hint of leather from the new Barcelona chairs and the bathroom ceiling”; followed by a smell reminiscent of American men in the 1950s, echoing notes from the most popular *eau de cologne* and introducing a human element in the reconstruction, which evokes the history of the house as a place for gatherings. Finally, the third smell captures the history of the house 20 years after the first one. The recreators of the aromas had to deal with a lack of written records about the house’ smell, and rely instead in the visible change in materials that might have a connection to the olfactory, such as yellowed plaster in the ceilings denoting years of tobacco smoke or the peeling tiles in the bathroom accounting for humidity and lack of ventilation (Otero-Pailos, 2008).

Recreating a smell from the past in a historic building requires an understanding of the history of the space where that odour unfolded. It has been suggested that among the considerations for this task should be “the architect’s intention associated with smell, ventilation and air cleaning concept, social characteristics of people who have stayed in the house (members of the elite), etc. To preserve and experience the interior scent in its rich authenticity, all olfactory elements must be estimated separately. It means that it is necessary to consider all aspects that have historically affected the olfactory aesthetics of the house, until the present time” (Tosic, 2017). The concept of authenticity is central to smell preservation and reconstruction, and was discussed in depth in the previous chapter, in the context of a study to explore the perception of authenticity of a historic odour.

The smells of the Glass House, diffused intermittently through the building, are expected by the designers to provoke visitors by making them aware of how olfactory sensibilities have changed between the time when those odours were a result of the activity in the building and the present, where they are the result of an exercise of experimental architecture preservation.

Those smelling the historic pot-pourri reconstruction identified as historic at Knole, which will be discussed at length in the next section, also realised how a smell from the past can highlight a change in time and practices, this time around domesticity. Surprise, nostalgia and a feeling of otherness are some of the observed reactions that subjects sniffing Knole's historic pot-pourri had towards the scent. Spontaneous comments when first approaching the smell for the first time referred to how the pot-pourri reminded them of the smell of older relatives' homes, and how for many it is the scent of something old, one that they would not voluntarily diffuse in their contemporary homes.

9.1 Knole's Pot-pourri experiment results & discussion

9.1.1 Cultural significance

Pot-pourri is a mixture of petals, spices and salts to aromatise the home, popular in Britain in the 17th and 18th centuries. Many British houses, including Knole, a 15th-century property in Kent, England, had their own recipe. Modern equivalents are candles, reed diffusers, timed perfume-sprays and other options involving technology. Following a renaissance in the 20th century, when exclusive blends of pot-pourri were advertised in interior design magazines by the 1970s, The New York Times reports that it was such an unusual sight in domestic environments that people mistook it for party food and ate it (Dullea, 1990). The disappearance of potpourri is not just about the fact that the traditional mixture is less available; the practices and knowledge related to the selection of ingredients and preparation of the pot-pourri have also become a thing of the past (Dullea, 1990). Ever since the 1970s, the mixture of dried flowers has experienced brief periods of popularity but has definitely lost its original appeal, currently accounting for just 2% of a growing home fresheners market valued at £367 million in the UK (The Telegraph, 2011).

Figure 9-1. Knole House exterior. © Robert Morris / National Trust.

Several members of the Sackville-West family, who built the house and whose descendants live there to this day, have been writers or acquainted with writers. Many mentions of the pot-pourri were found in their published texts, including in the novel *Orlando*, by Virginia Woolf, set at Knole, whose protagonist “buried her face in the pot-pourri, which was made as the Conqueror had taught them many hundred years ago and from the same roses” (Woolf, 1998). Vita Sackville-West wrote about the smells of the galleries of her childhood home: “They have the old, musty smell which to me, whenever I met it, would bring back Knole. I suppose it is really the smell of all old houses – a mixture of woodwork, pot-pourri, leather, tapestry, and the little camphor bags which keep away the moth” and specifically about the pot pourri: “bowls of lavender and dried rose-leaves stand on the window-sills; and if you stir them up you get the quintessence of the smell, a sort of dusty fragrance, sweeter in the under layers where it has held the damp of the spices. The pot pourri at Knole is always made from the recipe of a prim-looking little old lady who lived there for many years as a guest in the reigns of George I and George II” (Sackville-West, 1923). And then, the recipe created in 1750 by Lady Betty Germaine, a courtier of Queen Anne who lived at Knole, had been published: “Gather dry, double violets, rose leaves, lavender, myrtle

flowers, verbena, bay leaves, rosemary, balm, musk, geranium. Pick these from the stalks and dry on paper in the sun for a day or two before putting them in a jar. This should be a large white one, well glazed, with a close fitting cover (…) Layer of bay salt above and below every layer of flowers. Have ready of spices, plenty of cinnamon, mace, nutmeg and pepper and lemon peel pounded. For a large jar half pound of orris-root, one ounce storax, one ounce gum benjamin, two ounces of calamo aromatico, two grs. musk, and a small quantity of oil of rhodium (…) mix all well together and spread bay salt on top to exclude air until the January or February following" (Jekyll, 1900).

The potpourri reconstruction was prepared by perfumer Stephen Nelson for Knole. "I first came across the Lady Betty Germaine recipe in a 1900 publication *Home and Garden* by Gertrude Jeykll, the celebrated garden designer" he writes in his blog (Nelson, 2006). "Gertrude takes up a complete chapter on the making of pot-pourri where she gives details of her own recipe filling a fifteen gallon barrel with the finished product. She then gives mention to the Lady Betty recipe, handed to her by Vita's mother Victoria (...). Gertrude would make enough pot-pourri to give to friends and family including the Lutyens' and her sister-in-law Agnes, whose home, Munstead House in Surrey was described as 'the apogee of opulent comfort and order without grandeur, smelling of pot-pourri, furniture polish and wood smoke".

The pot-pourri is currently displayed at Knole in a windowsill on the first floor, or in Lady Betty's room, depending on which space is open to the public at the time. The mixture is contained in a ceramic bowl that is part of the house collection (Fig.10-2). The height of the window display means only the taller visitors get a sniff.

Figure 9-2. Display of pot-pourri in Knole's showrooms. Left: a visitor by the pot-pourri display on a first floor windowsill. Centre: a close-up of the pot-pourri. Right: the pot-pourri display in Lady Betty's room.

The box containing the individual components of the pot-pourri, also prepared by Nelson, is used for public engagement purposes by Knole's visitor experience team, and in these sessions with smaller groups participants can smell the pot-pourri as a mix and also as separate ingredients.

9.1.2 Chemical analysis

A total of 122 chemical compounds were identified in the sample, distributed over a 48-min chromatogram, with the highest concentration of peaks to be found between 27 and 42 min. They were automatically grouped by the deconvolution software (Targetview V3, Almsco) as alcohols, aldehydes, aliphatic hydrocarbons, aromatic compounds, cyclic hydrocarbons, esthers, ethers, halogen-containing compounds, heterogroups, ketones, nitrogen-containing compounds, organic acids, oxygen-containing compounds and terpenes.

The ten compounds listed in Tab.10.1 were the most abundant in the sample. A higher abundance of a compound does not, however, make it detectable by the human nose, as it is shown by the results of the GC-O analysis below. In spite of being present in higher concentration, the smell of several of the compounds was not detected, possibly because the threshold that makes it detectable to the human nose was not reached.

Compound	CAS Number	Chemical Group
Decane	124-18-5	Aliphatic Hydrocarbons
Furfural	98-01-1	Oxygen-containing compounds
Acetone	67-64-1	ketone
Undecane	1120-21-4	Aliphatic Hydrocarbons
Acetic acid	64-19-7	Organic acid
Phenylethyl Alcohol	60-12-8	Alcohols
Benzaldehyde	100-52-7	Aldehydes
t-Terpinene	99-85-4	Terpenes
Isopropyl Alcohol	67-63-0	Alcohols
(-)-β-pinene	18172-67-3	Terpenes

Table 9-1. Compounds with highest abundance in the sample, as identified in GC-ToF-MS analysis.

9.1.3 Sensory analysis

GC-Sniffing

A total of 24 smells were identified by GC-O. Around 40% of those smells were correlated to chemical compounds present in the sample, as can be seen in Tab.10-2 (for the limitations of chemical identifications in GC-O, as well as potential reasons for discrepancies between the GC/MS and GC-O findings, please refer to the discussion of GC-Sniffing findings in the previous chapter).

Green, floral, herbal and spicy odours predominated, as expected, with the highest frequency occurring between 28 and 44 min.

In terms of hedonic tone, most of the odours were perceived as pleasant or neutral, with a few exceptions characterised as unpleasant (at 26.3, 36, 39.1 min).

Regarding the chemical compounds identified as sources of perceived smells during the task, acetic acid has a sour, vinegar-like odour (Acree and Arn, 2010) often a product of cellulose degradation (Mosciano, 2019). 1-hexanol smells pungent, ethereal, fusel alcohol, fruity and alcoholic, sweet with a green top note

(Mosciano, 2019). It is naturally occurring in rose otto, lavender and violet oil (Luebke, 1995), all present in the sample. Beta-pinene has a dry woody resinous pine hay green smell (Luebke, 1995) and it is present in calamus, cassia bark, cinnamon, lavender and laurel oil, lemon, myrtle, nutmeg, pepper and rosemary oil (Luebke, 1995), components that are all present in the sample. 3-octanone is present in many plant, fruit and flower aromas; has a fresh herbal lavender sweet mushroom smell (Luebke, 1995), also described as pungent (National Center for Biotechnology Information, 2019). Its likely sources in the sample are bay leaf, lavender and rosemary. 2-ethylhexanol is a natural component of rose aroma and could correspond with the presence of rose petals in the sample. It has been characterised as citrus, green, oil, rose (Nijssen, L.M.; Ingen-Visscher, C.A. van; Donders, 1963-2018).

T1	Intensity	Descriptors GC-O	Published descriptors	Compound	CAS
16.29	2	vinegar, sour, acid	n/a	n/a	n/a
17.33	1	mushroom, toasted, acid	sour (I)	acetic acid*	64-19-7
22.33	3	rubber, synthetic, fruity	n/a	n/a	n/a
26.32	2	unpleasant, rotten, fermented	n/a	n/a	n/a
27.4	2	tea, green, hay	pungent, ethereal, fuel oil, fruity and alcoholic, sweet with a green top note (II)	1-hexanol	111-27-3
30.57	2	lemon, metal, rain, green	n/a	n/a	n/a
31.3	2	green, lemon, flowers	dry woody resinous pine hay green (III)	ß-pinene	127-91-3
32.12	1	fresh, herbal, dry grass	fresh herbal lavender sweet mushroom (III) pungent (IV)	3-octanone	106-68-3
33.57	2	fresh, green, synthetic, floral, mothballs	citrus fresh floral oily sweet (III) citrus, green, oil, rose (V)	2-ethyl-1-hexanol	104-76-7
36.02	3	peroxide, pungent, unpleasant	n/a	n/a	n/a
36.35	2	petals, flowers, sour	fat, citrus, green (I)	nonanal*	124-19-6
37.12	2	plastic, hand cream, powder	n/a	n/a	n/a
37.3	2	licorice, dry straw, organic	n/a	n/a	n/a
38.54	2	flower, petal	n/a	n/a	n/a
39.16	2	organic, unpleasant, fried food	n/a	n/a	n/a
39.47	3	organic, roses	camphor, earth, green (V)	isobornyl formate	1200-67-5
42.14	2	broth, oily, gasoline	ink-like, leather-like, medicinal (IV)	3-isopropylphenol	618-45-1
43.33	2	cinnamon	cassia, cinnamon, cinnamon bark and red hots (II)	3-phenyl-2-propenal	104-55-2
47.53	2	cinnamon, pleasant, vegetable, fresh, pine	n/a	n/a	n/a

Table 9-2. Odours registered during GC-O analysis of the sample. T1 indicates the time the analyst first perceived the smell. The asterisk (*) next to a compound name indicates that it was not possible to fully validate the identification. Published odour descriptors: (I) Heinrich Arn (2004), (II) Mosciano (1997), (III) Luebke (1995), (IV) National Center for Biotechnology Information (2019) (V) VCF (2016), (VI) Czerny et al. (2011).

Nonanal occurs naturally in many essential oils, and it is present in cinnamon, rose and lemon (Luebke, 1995), which are all in the pot-pourri. It smells fat, citrus, green (Acree, T and Arn, 2004). Isobornyl formate has a camphor, earth, green smell. It is emitted naturally by the *Anthemis coelopoda* plant, pertaining to the chamomile family (Luebke, 1995). 3-isopropylphenol has an odour described as ink-like, leather-like and medicinal (Czerny *et al.*, 2011). It is naturally present in *Helichrysum italicum*, or curry plant (Luebke, 1995). 3-phenyl-2-propenal, also known as cynnamaldehyde, is the main compound responsible for the smell of cinnamon.

Figure 9-3. Wordcloud featuring the most frequent descriptors for the odours detected by GC-O. Descriptors were multiplied by intensity to offer a more accurate representation of the sensory profile.

Panel evaluation

A group of 8 assessors, composed by members of Knole conservation and visitor experience teams, and volunteers working in the house, recorded their evaluations of the smell after smelling a bowl of pot-pourri inside the house. Within the given list, 'cinnamon, spices' was the descriptor of the list selected by the 7 assessors, followed by 'floral' (6 people), 'earthy' and 'sweet' (both 5 people) and vanilla (4 participants), as shown in Fig.10-3. The smell was also described

as ‘dry hay, dry grass’, ‘organic’, ‘roses’ and ‘tea’ by 3 of the panellists. Finally, 2 noted a ‘citric’ quality to the smell, and one attributed the ‘mothballs’ and ‘toasted’ descriptors to the sample. Odours perceived repeatedly in the GC-sniffing analysis such as ‘rubber, synthetic’, ‘eucalyptus’, ‘fermented, rotten’, ‘mushroom’, ‘oily’ and ‘sour’ were not identified by the sensory panel. As per the visual and verbal cue influence on odour classification, it was observed that the relation of these findings to the visual cue of the sample (since the experiment was conducted using a visible pot-pourri sample, the participants could see flower rose petals and cinnamon bark, among other ingredients) and the verbal context of the given odour descriptors is extremely relevant to the results, corroborating the findings of a great deal of published works (for example R S Herz, 2003; Herz 2001; Ayabe-Kanamura 1998). However, the role of verbal cues on interpretation of smells in a heritage context needs to be further investigated. An experiment discussed in the next chapter takes the first step towards this exploration.

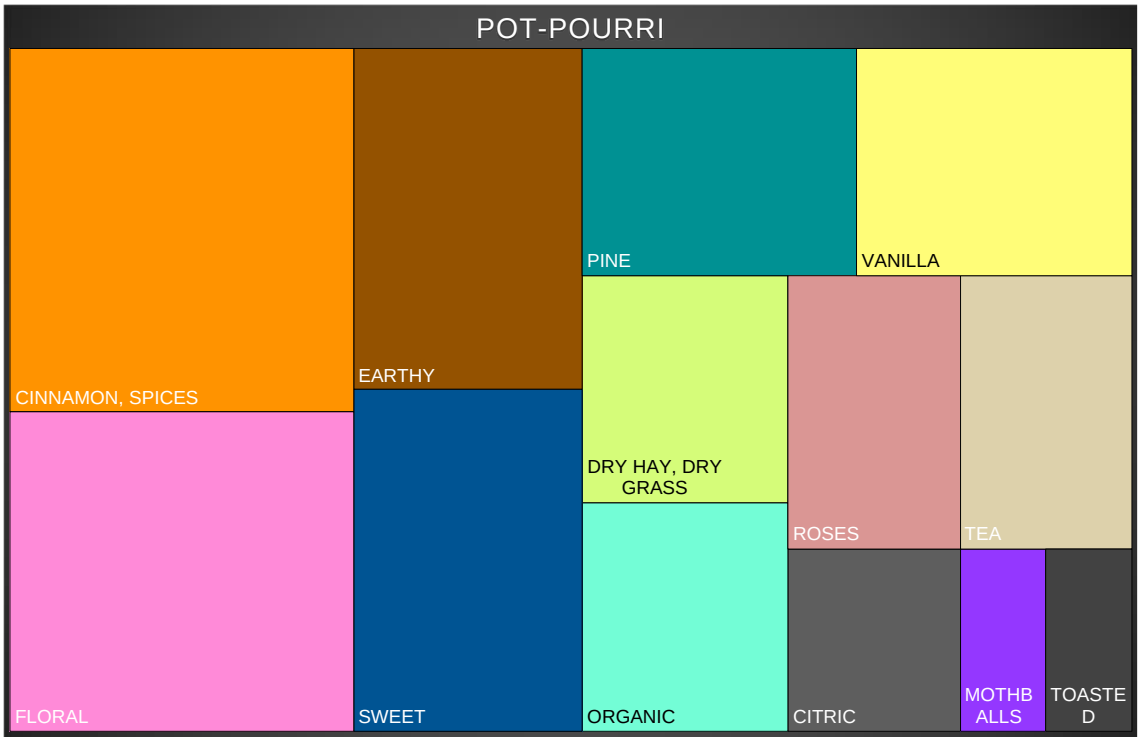


Figure 9-4. Odour quality descriptions from panel evaluation. Area size correlates with frequency of use of the descriptor during the study.

With regards to intensity, the 9 panellists evaluated the intensity as ‘4 - strong’ (3), ‘3 - distinct’ (5) and ‘2 - faint’ (1), with the average of 3.2 being between ‘distinct’ and ‘strong’.

Finally, the panellists rated their perceived pleasantness or unpleasantness (hedonic tone) of the library odour. On a scale that ranges from -4 (‘very unpleasant’) to +4 (‘very pleasant’), hedonic tone average was 1.89, between ‘mildly pleasant’; and ‘moderately pleasant’.

A few findings in this study merit discussion:

Several of the smells identified and named by the sensory panel, such as cinnamon, spices and roses, correspond to the ingredients for the pot-pourri. A possible explanation for this is that they are everyday odours to which most of the panellists might have been frequently exposed, and therefore developed familiarity and the ability to identify them, in line with previous findings indicating that repeated exposure improves odour identification (Morquecho-Campos *et al.*, 2019).

In terms of hedonic tone, panellists who assessed the sample of pot-pourri in the historic house found it more pleasant that analysts assessing via GC-O, who labelled the smells ‘unpleasant’ on several occasions, to the point that became an important descriptor for the smell. These differences can be partially explained by the fact that non-olfactory information affects odour perception and evaluation, and expectations play an important role in hedonic tone judgement (Rachel S. Herz, 2003). For example, people tend to like a wine more if they are told it is expensive (Schmidt *et al.*, 2017). In this case, panellists rating a historic odour in a historic house might have a different pleasantness threshold than panellists in the lab. The first group are evaluating the sample as a whole, with the knowledge of its significance and in a historic setting. The second group is evaluating the compounds in isolation and out of context, as per the nature of GC-O. An additional factor would be that, by being evaluated in a historic environment, a historic smell might be perceived as more authentic in the sense discussed in the previous chapter, where one aspect of authenticity is the thematical congruence between olfactory and non-olfactory factors (Doucé *et al.*, 2013).

Finally, the fact that a historic smell might have been designed to cater to a contemporary sensibility has to be noted, as the fact that the desired effect (pot-pourri was meant to smell pleasantly and make the rooms fragrant) might not

have survived through time, with the changes in personal hygiene, housekeeping and refrigeration bringing about a change in olfactory tolerance and taste, as argued by many researchers (Classen, C, Howes, 1994; Smith, 2014).

9.1.4 Historic pot-pourri odour wheel

In order to combine the chemical and sensory information, an odour wheel was developed. The resulting wheel is a documentation piece for public engagement and archiving purposes, by enabling a potential reproduction of the smell.

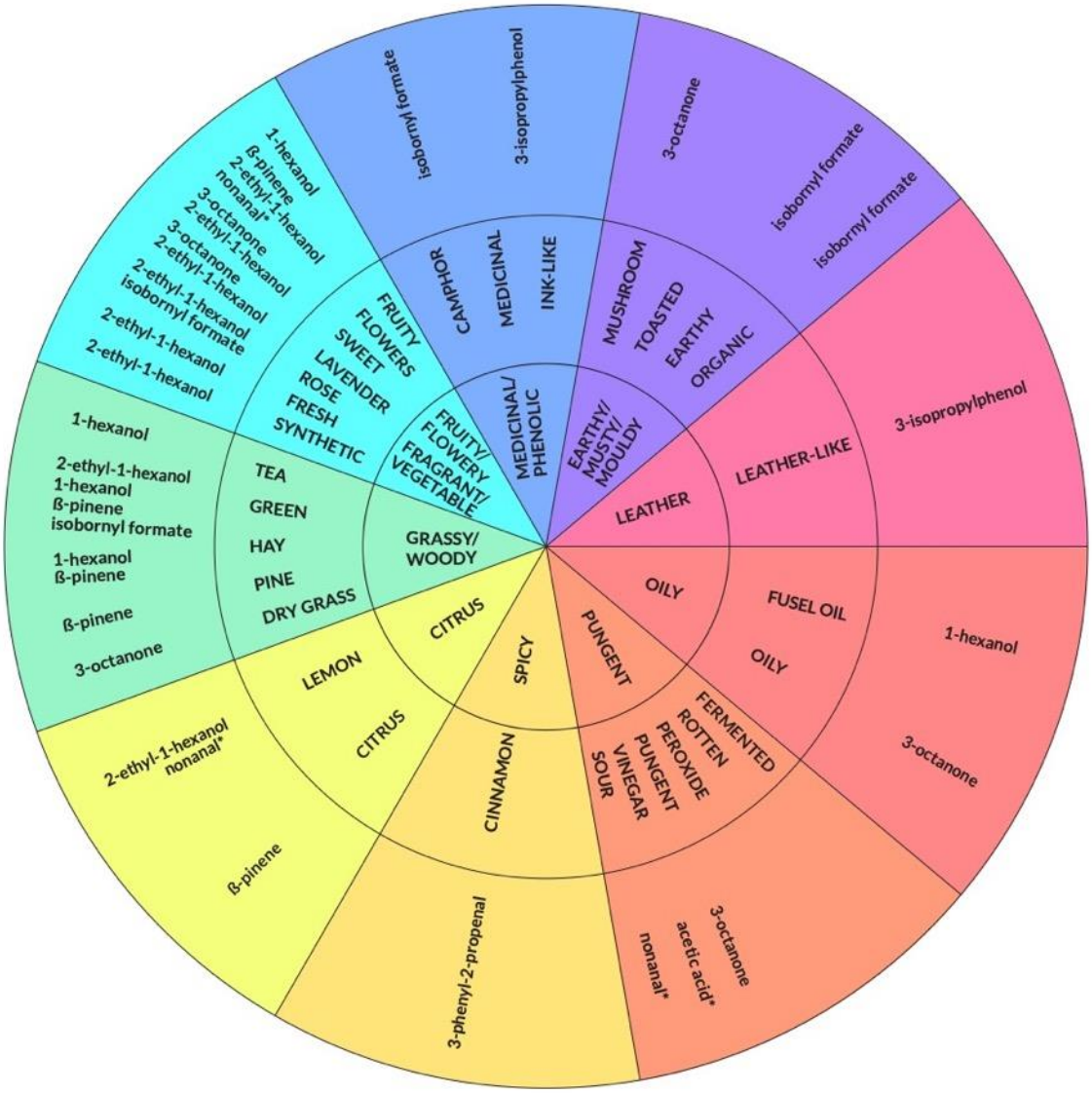


Figure 9-5. Odour wheel of historic pot-pourri containing general aroma categories, sensory descriptors and chemical information. The asterisk (*) next to a compound name indicates that it was not possible to fully validate the identification (see methodology section for details). Colours are arbitrary.

9.2 Chapter summary

- Olfactory preservation is a field of interest to architects, perfumers and conservators, and it has potential to engage other aspects of heritage practice, such as visitor experience, curation and interpretation. When reconstructing a sensory experience of the past, considering the smell, the environment that produced it and the dynamics between both in the creation and presentation of the new odour can result in a much richer, more meaningful experience, both in sensory and in historic terms. Capitalising on this opportunity requires thinking about smells and their connection to objects and spaces over time, and unfolding an interpretation where a smell, far from being incorporated as an oddity or an afterthought into a display, can become an anchor for the narrative, a bridge between objects, stories, spaces and the people who once inhabited them.
- Pot-pourri is not as popular today as it once was; and with its disappearance the practices and knowledge related to the selection of ingredients and preparation are also a thing of the past. The smell is also interpreted today as a historic one, as evidenced by the sensory findings of this study.
- Non-olfactory information affects odour perception and evaluation, and expectations play an important role in hedonic tone judgement. This study shows that in a historic house, a historic odour is perceived as more pleasant than in the lab.
- The pot-pourri odour wheel is a new tool that enables, within the limitations discussed in the previous chapter, understanding and documenting the odour experience through articulating chemical and sensory information. Visitor experience and collection interpretation could use it to engage and educate visitors, offering new and inclusive information, promoting awareness about olfactory perception and contributing to a more personal experience of heritage.
- The findings of this study suggest a careful consideration in the

presentation of historic smells as part of the narrative of a space or collection and for public engagement, both in the olfactory and non-olfactory components. A contextualised integration of smells into displays and exhibits, alerting the visitors of the changes in sensibility and functions of the odours, and using the opportunity to highlight connections between a historic environment and historic smells, might contribute to the perception of the odours as authentic and might influence the overall pleasantness and engagement of the experience. My study shows there is an opportunity to further develop the pot-pourri display at Knole into a glimpse into the sensory past.

10 Visible and invisible. Characterisation of Knole's perfumed wax and study of visitors' engagement

In addition to making a contribution to the systematic analysis of smells with cultural significance, this work aims to engage in a dialogue with some of the more conceptual aspects of human olfaction and olfactory perception, in a way that could inform a discussion of olfaction in heritage. In this chapter, the case study presented an opportunity to explore the relevance of the odour source in a historic house in terms of smell perception and characterisation. It also looked into visitors' engagement with smells in comparison with other sensory stimuli during a visit to the showrooms.

The findings are presented therefore in two connected parts: the first one accounts for the analysis and documentation of the smell of a perfumed conservation wax as a heritage smell, as well as its significance to Knole House. This was done following the framework presented in the Smell and heritage chapter. The second part presents a study on the value of odours to visitors during a summer exhibition of the showrooms at Knole, which included reactions to the smell of perfumed wax discussed in the first part of this chapter.

The wax was originally selected because it could be considered as an odour from an invisible source (once a furniture wax is applied and buffed, it disappears from sight, and the scent lingers) and was therefore ideal to compare the impact of a smell which is not anchored in an object, or a person, but that once released into the air becomes part of the 'atmosphere of the place'. In this sense, this case study relates to an ongoing discussion on olfactory perception and the need to consider it independently from other forms of sensory perception. Although we are used to account for our visual and auditory perception in terms of objects rather than sensations ('the clock chimed'), the notion of object is currently being questioned in the context of olfactory perception. One of the reasons for this lies with the fact that the link between the source of the smell and perception is weaker and less direct than the link

between the source of light that causes visual perception and the perception itself (Keller, 2017). Keller (2017) also reviews several proposals that have been put forward as olfactory objects: the source of an odour (object view), the odorous molecules given off by it (cloud object view), the molecules that bind to our olfactory receptors (molecule cloud view, where the object is the chemical structure). He accounts for another view, which poses that the olfactory object is what is phenomenally present in a given instance of perception. Background knowledge of the perceiver would in this case identify the object of olfactory perception as either the source or the molecules, for example, and therefore the object would not be fixed. Barwich (2013) proposes to approach olfactory perception as a process, with a "richer characterisation of the modalities of the perception process in order to make sense of scent. Smell, it will become clear, is not only a result of a perception process but must also be understood and analysed as a process in itself" (Barwich, 2014).

In addition to the complexity of identifying the role of the smell source in its perception, there are ethical implications to be considered when a smell with no visible origin and no explicit author is present in a heritage space. Discussing the relevance of the smell's source visibility in scented art in museums, Drobnick notes that "it is often the case that a 'pure' olfactory artwork, consisting simply of a scent diffused into the space, can be more difficult for a general audience to perceive as art, for two reasons. One is that, because of its invisibility, visitors may not realize that an olfactory work is present, or which scent in the space is actually the artwork (an attendant's perfume, or the hint of car exhaust coming through the window?). The other reason is that smell's elusiveness leaves it open to manipulation through language, as many perfume marketers know. Contextualizing elements such as labels can provide valuable clues about what is to be experienced and how visitors should react" (Levent and Pascual-Leone, 2014). When the source is invisible, the curator has an added responsibility: to dispel visitors concerns. "Audiences tend to be suspicious of and annoyed at smells they cannot readily identify, especially if they are anonymously introduced", says Drobnick, noting that "the feeling of manipulation may arise when the purpose of the scent is not evident". These ethical preoccupations

distinguish the heritage space from the retail environment, where scents are frequently, and anonymously diffused (and even in spaces such as nature and sciences museums, where the purpose of the smell is more instrumental than artistic, he questions the value of using synthesised scents).

10.1 Knole's Wax experiment results & discussion

10.1.1 Significance assessment

The inclusion of a conservation product in the selection of heritage smells relating to Knole was considered in relation to authenticity, and the understanding that one of the routes to preserving an authentic smell in context is allowing the environment to smell of what it actually does, or to "smell what you see" (Henshaw, V., McLean, K., Medway, D., Perkins, C., & Warnaby, 2017). In this sense, a care product for furniture is a reminder to visitors that the property being toured once was (and still is, in the part of the house currently lived in by the Sackville-West family) a domestic environment.

The conservation team at Knole uses several products to clean and maintain surfaces in the house. Perfumed waxes were of special interest, because their smell stays once it is applied. In order to select a scented wax, three products were originally considered in consultation with the conservation team working in the house. Firstly, Harrell's Wax Polish, a product manufactured by W. S. Jenkins & Co. Ltd., a family run business, in their London factory since 1931. It is a unique blend of pure beeswax and other natural waxes. In National Trust buildings, this wax is used on furniture by conservators "buffed into the wood and helps to create a protective barrier" (Mayhew, 2018). The smell of Harrell's wax is described as a "clean fresh scent" and "great fragrance" in product marketing copy (Harrel's, 2019). The second product investigated was Diversey Bourne Traffic Liquid Wax, a solvent-based wax floor polish for traditional maintenance of wood floors. The smell is described as "slightly perfumed" (Diversey, 2015). The third product considered was Wax Polish Black Bison Paste, used for protecting all types of

wood, made from a blend of waxes, including carnauba wax. This wax is claimed by the manufacturer to be “well-known for its quality and pleasant, distinctive aroma” and it is endorsed by the Guild of Master Craftmen. The team at Knole uses the Dark Oak version of this wax on wooden floors and furniture in different rooms, including the Great Hall and Stairs.

After sampling and analysis the three waxes, Wax Polish Black Bison Paste was selected for the case study due to the presence of many odorants in the chromatograms and deconvolution and extended evidence of perception of its distinct smell as recorded on furniture care online forums, where restorers discussed the properties of the product: “My preference is the (Black Bison) Liberon because it feels and smells nicer than the Briwax’(Retired, 2015), “Black bison I hate - horrible hues and smell”, “I like the smell of the black bison wax”, “about Black Bison pong - just don't like it” (Pebbles, 2014).

10.1.2 Chemical analysis

Before investigating the volatile organic components emitted by the wax, the ingredients in the product as reported in the safety sheet were noted as hydrocarbons, C9-C11, n-alkanes, isoalkanes, cyclics, <2% aromatics and alfa-pinene (CAS 80-56-8, <2.5%).

Over 300 compounds were found in the sample, in 48 min of analysis, with the highest number of peaks between 18 and 38 min.

The 25 most abundant compounds are shown in Table 10-1; together they make for 54% of the total peak area. A higher abundance of a compound does not, however, make it detectable by the human nose, as it is shown by the results of the GC-O analysis below.

Compound	CAS No.	Chemical group
Cyclohexane, 1,3-dimethyl-, cis-	638-04-0	Cyclic Hydrocarbons
Cyclohexane, 1,4-dimethyl-, cis-	624-29-3	Cyclic Hydrocarbons
Cyclohexane, 1,2-dimethyl-, trans-	6876-23-9	Cyclic Hydrocarbons
3-Hexanone, 2,5-dimethyl-	1888-57-9	Ketones
Cyclohexane, 1,3,5-trimethyl-	1839-63-0	Cyclic Hydrocarbons
Octane, 3-methyl-	2216-33-3	Aliphatic Hydrocarbons
Octane	111-65-9	Aliphatic Hydrocarbons
Cyclohexane, methyl-	108-87-2	Cyclic Hydrocarbons
Cyclohexane, 1,4-dimethyl-, cis-	624-29-3	Cyclic Hydrocarbons
Heptane, 3-methyl-	589-81-1	Aliphatic Hydrocarbons
2-Pyrazoline, 1-isopropyl-5-methyl-	26964-54-5	Nitrogen-containing compounds
Heptane, 2-methyl-	592-27-8	Aliphatic Hydrocarbons
Undecane	1120-21-4	Aliphatic Hydrocarbons
Naphthalene, decahydro-, trans-	0493-02-07	Cyclic Hydrocarbons
Phenylethyl Alcohol	60-12-8	Alcohols
Cyclohexane, 1-bromo-4-methyl-	6294-40-2	Halogen-containing compounds
Naphthalene, decahydro-2-methyl-	2958-76-1	Cyclic Hydrocarbons
Cyclohexane, 1,3,5-trimethyl-	1839-63-0	Cyclic Hydrocarbons
Cyclohexane, (1-methylethyl)-	696-29-7	Cyclic Hydrocarbons
Cyclohexane, 1,3,5-trimethyl-, (1a,3a,5ß)-	1795-26-2	Cyclic Hydrocarbons
Heptane, 4-methyl-	589-53-7	Aliphatic Hydrocarbons
1H-Indene, octahydro-5-methyl-	19744-64-0	Cyclic Hydrocarbons
Decane, 3-methyl-	13151-34-3	Aliphatic Hydrocarbons
Trans-1,4-diethylcyclohexane	13990-93-7	Cyclic Hydrocarbons
Heptane, 5-ethyl-2-methyl-	13475-78-0	Aliphatic Hydrocarbons

Table 10-1. Compounds with highest abundance in the sample as identified by GC-ToF-MS analysis.

10.1.3 Sensory analysis

GC-Sniffing

A total of 50 smells were identified by GC-O, of which 17 were confirmed by two or more analysts. A percentage (around 47%) of those smells were correlated to chemical compounds present in the sample, as can be seen in Table 10-2.

Accuracy in the identification of odour-active compounds using GC-O may be affected by the high number of co-elutions that can occur during analysis (d'Acampora Zellner et al., 2008) and the fact that the human nose is more sensitive than most GC detectors for certain odour compounds (Acree, 1994).

In addition, chemical identification in GC-O, matching perceived odours with eluted compounds, presents a series of limitations due to the complexity of this type of analysis and the many factors linked with chromatographic parameters as well as the variables related to human perception. Some of these limitations, which might account for discrepancies between the TD-GC/MS and the GC-O results, are: that some compounds are present at concentrations lower than the instrumental detection limit, so sometimes smells perceived by the human detectors cannot be correlated to GC/MS findings; co-elution of compounds may easily occur making the correlation between the chromatographic peaks and the perceived aroma difficult to assess (Brattoli et al., 2013); the fact that olfactory capacity and odour thresholds may vary significantly both within and between people; missed stimulus by the human assessor due to lack of concentration, breathing cycle, etc (Giungato et al., 2018).

With regards to the wax analysis, sweet, floral and spicy odours predominated, as expected, with the highest frequency occurring between 27 and 46 min. In terms of hedonic tone, most of the odours were perceived as pleasant or neutral by the analysts.

T1	Intensity	Descriptors GC-O	Published descriptors	Compound	CAS
27.04	1	alcohol, chemical, fresh	n/a	n/a	n/a
27,37	1	sweet, fruity, spicy	sweet, like benzene	p-Xylene	106-42-3
31.35	3	fresh flowers, orange blossom	green, metal, pungent	Methyl vinyl ketone	78-94-4
34.00	2	sweet, floral, mothballs	n/a	n/a	n/a
34,10	2	mushroom	n/a	n/a	n/a
34,50	3	lactic, creamy, perfumed	n/a	n/a	n/a
36,30	3	rose, talcuum powder, dense	n/a	n/a	n/a
37,39	3	rose, talcuum powder, essential oil	n/a	n/a	n/a
38.00	2	lactic, creamy, perfumed steam	sweet floral fresh bready rose honey	Phenylethyl Alcohol	60-12-8
39,38	2	rose, aniseed, licorice, perfumed mothballs	waxy, almond, honey, jasmine, sweet, floral, fruity, spicy	Benzeneacetic acid, methyl ester	101-41-7
39.40	2	minty, menthol	oil, anise, mint , pine, lilac	a-Terpineol	98-55-5
41.42	1	caramel, sweet	floral, fruit, honey, rose, tobacco	Acetic acid, 2-phenylethyl ester	103-45-7
46,15	3	incense, insecticide, perfumed	n/a	n/a	n/a
46.36	4	show polish, blackberry, fruity, synthetic	n/a	n/a	n/a

Table 10-2. Odours registered during GC-O analysis of the sample. T1 indicates the time the analyst first perceived the smell. Referenced descriptors are from Flavornet, Mosciano and VCF databases.

Panel evaluation

Three quarters of evaluators (12 people) agreed that the sample smelled like 'shoe polish' and described the smell as 'synthetic', making these the most frequent descriptors of odour quality. 'Almond' was the third most frequent descriptor, selected by 8 participants, followed by 'sweet', with just over 7 participants in agreement. 'Fatty', ‘insecticide' and 'mothballs' were descriptors used by 6 participants, while 5 thought the smell could be characterised as 'spicy', 'aniseed', 'floral', 'fresh', 'rubber', and 'talcum powder'. 'Rose', 'damp' and 'fruity' were descriptors chosen by 3 people, 'dry grass', 'smoky', 'creamy', 'honey', 'mouldy', 'green' and 'liquorice' selected by 2, and finally one evaluator thought the wax smelled like 'cinnamon', 'chamomile', 'incense' and 'pepper' when they had to select among given descriptors. In addition, assessors volunteered the following descriptions of the smell: 'mango', 'mushroom', 'marker pen', 'acid', 'solvent', 'paint', 'bitter', 'balsamic', 'wood', 'old' and 'building site' (each selected

by one member of the panel).

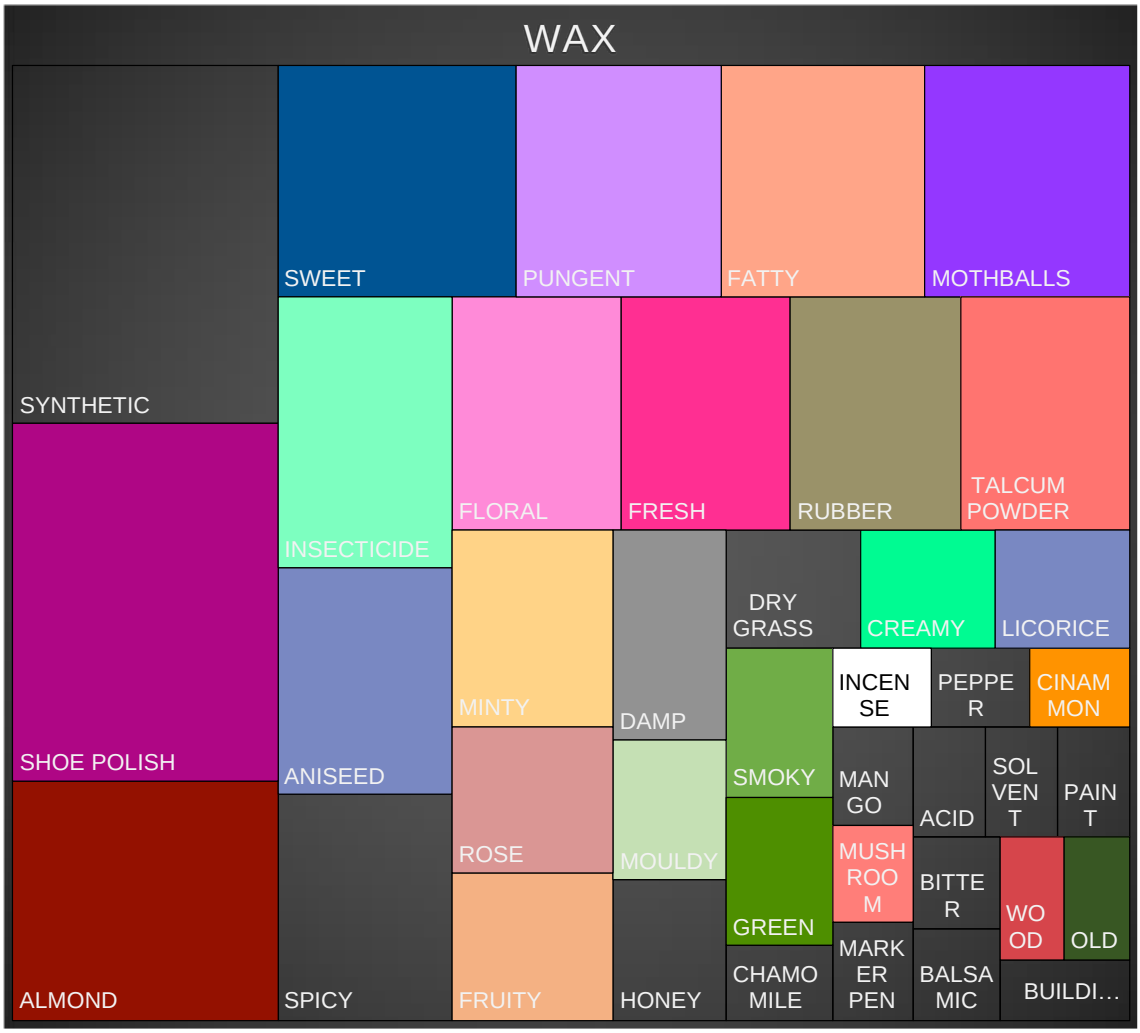


Figure 10-1. Odour quality descriptions from a panel evaluation of 16 participants. Area size correlates with frequency of use of the descriptor during the study

The hedonic tone of the wax smell was also evaluated using the technique of polarity profiles. These consist of 29 pairs of opposing adjectives (‘weak’/’strong’) with a 7-point scale in between. Assessors rate their perception of the smell according to this list, and the semantic differential is calculated and correlated with reference values for ‘smell’ and ‘stench’ obtained with the same technique (see example in Appendix III). For the purpose of this experiment, own values for ‘smell’ and ‘stench’ were also calibrated with the panel. In the reference values, a negative correlation of -0.86 can be measured between the two variables, in the case of the panel of evaluators used for this experiment, a negative correlation of -0.74 was measured. According to the standard, for an odour to qualify as hedonically definitely pleasant, the correlation between the profile of

the odour and the representative fragrance and stench profiles has to be greater than 0.5 and less than -0.5, respectively (the normative focuses on facility odours). In the case of the wax, the correlation with the panel-measured stench was positive (0.5) and the one with scent was negative (-0.03). Although the profile comes closer to the stench profile than to the scent profile, the quality of the wax smell cannot be termed definitely unpleasant.

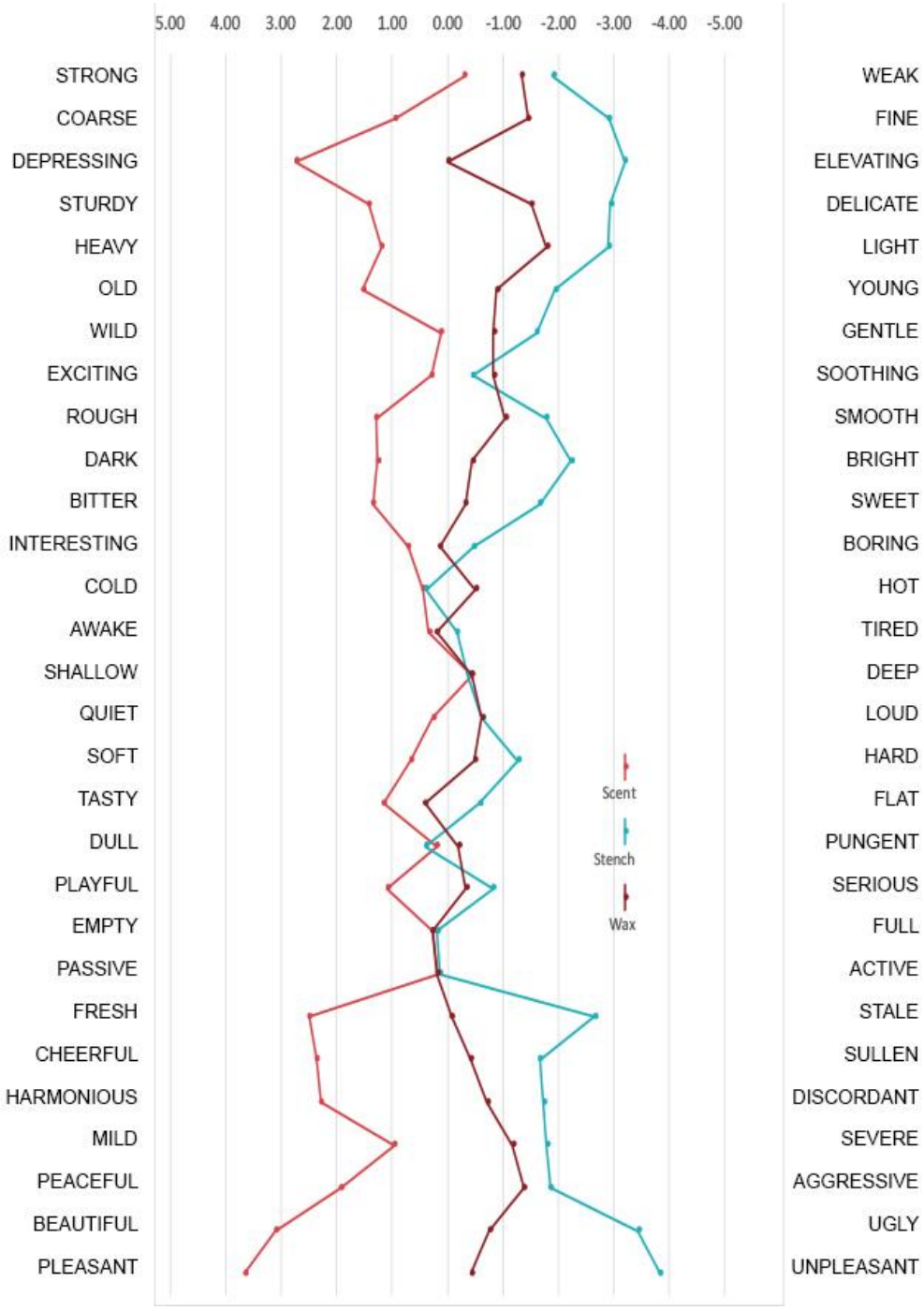


Figure 10-2. Polarity profile from panel evaluation (n=16). Participants were asked to rate the idea of a pleasant smell (scent), an unpleasant smell (stench) and their experience of the wax smell (wax).

10.2 Odours and visitor experience in a historic house: a study of value

As discussed in the introduction to this chapter, one of the objectives of this investigation into the role of olfaction in heritage was to study how smells impact on a heritage experience, and to better understand the value they potentially add to a visit.

Firstly, and given the variety of odours that can be found in a historic house, the few smells chosen for this study must be briefly contextualised, since a reference classification for historic smells (similar to those devised for perfume (Edwards, 2012a), wine (Noble *et al.*, 1987) or urban odours such as waste waters (I. H. Suffet and Rosenfeld, 2007)) does not exist at present; and although a formal typology is outside of the scope of this work, understanding the various types of historic smells analysed can provide an insight into how visitors value their presence.

In some cases, smells related to an object in a heritage space acquire a new identity that help perceive the passage of time (i.e. the scent of an old book, or a historic library, is different from that of a new book, but it is can still be evaluated as a smell related to a familiar object or space provided certain cues, such as visual identification of the source, are present (Bembibre and Strlič, 2017)). In other cases, the source of an odour for which there is documented significance is no longer available, but a historically accurate reconstruction is presented in its place, like Knole's historic pot-pourri (Bembibre Jacobo, C; Barratt, S; Vera, L, Strlič, 2017) as discussed in the previous chapter. A third type is an odour related to a building through conservation practice, as mentioned, and therefore signalling the significance of the heritage by caring and protecting objects or the fabric of the building itself: this is the case of the perfumed conservation wax used in Knole and characterised at the beginning of this chapter. The wax smell

emanates from an ‘invisible’ source and therefore it might have an advantage over other odours with visible sources in becoming part of the atmosphere of the house. Finally, odours can be a result of processes that affect historic spaces and objects, generally considered damage, such as mould. The focus of this chapter is on smells deliberately or incidentally present in a building at the time the public visits in a way that they are either part of the collection (because the material source is, so the odour is an attribute of that object or space) or because they are introduced into the space as a result of conservation practice. Incidental smells that are a result of material change (historic books) or damage (mould), as discussed elsewhere in this work, are not specifically addressed in this section.

When researching what the presence of specific smells can add to the value of a heritage experience, the role of scent in significance assessment needs to be considered. Overall, sensory stimuli are considered part of the aesthetic value of a heritage space, and smell is classed along with other sensory stimuli as either sources of pleasure or because they carry evidentiary, associative or functional qualities. Traditionally, these values focus on the visual but a deliberate effort is being made to use the word ‘sensory’ as a way to avoid the predominance of sight in value categorisation, evident in Western models (Fredheim and Khalaf, 2016). Historians note, however, that the occidental museum experience of the 17th and 18th century relied on senses other than sight, as touching the objects was considered an integral part of the collection tour (Classen, 2005).

More recently, the sensory aspect of heritage has been also the focus of atmospherics studies, which have been described as a sensory phenomenon (Forrest, 2013) and propose that the environment can be designed to have an impact on visitors’ affective, cognitive and behavioural responses (Forrest, 2013). This field, originally applied to understanding and improving the retail experience, has crossed over to study the interaction between museum visitors and how their experience can be shaped by factors such as light, temperature or smells in the building at the time of their visit.

And olfaction is, it seems, a sense that lends itself to these crossovers. It has been noted that the appreciation of visual arts is often somehow transformed into smells in the transition from the exhibition the museum's gift shop. Drobnick (2014) presents the example of a scented candle promising the scent of Monet's *Sunflowers,* a symbol of the painting to be taken and enjoyed in a domestic environment: "the aromatic equivalent of Monet's Sunflowers permits a fully embodied, though virtual, imbibing of the artwork. Breathing in the painting is almost tantamount to living within it, to incorporating it within one's being, a much different experience than viewing". Perhaps even more so than a museum, visiting a historic house is a multisensory experience, where visitors interact with many types of stimuli such as visual, auditory, olfactory and sometimes tactile. Our understanding of neuroscience and the way we respond to changes in our environment reveals that going around the showrooms in a heritage space presents an opportunity for the proposed visit by the institution to "literally shape visitors' brains" (Levent, N. S., & Pascual-Leone, 2014).

The role of each sensory input in multisensory experience is still being investigated, but it has been established that in an environment in constant change, stability of perception depends on the ability to integrate information from different modalities (Gotow and Kobayakawa, 2017). The study of the interaction of perception via all senses is a field where various theories exist, mainly the sensory dominance approach (concerned with perception and resolution of intersensory conflict) and the multisensory integration approach, focused on temporal response to multisensory stimuli (Calvert, G., Spence, C., Stein, 2004).

How does this work in practice? How are the presence of smell and the conditions of its presentation valued by visitors to the building, and what role does the olfactory element play in the rich sensory experience of the visit?

In order to gain insight into these matters, a study was carried out in Knole House, where on Day 1 an already existing olfactory component of the collection was chosen and its source highlighted by a sign detailing its significance, on Day 2

this same setup was enhanced by the presence of a facilitator, on Day 3 a smell linked to conservation practice with an invisible source (wax, as discussed in the previous chapter) was added, and on Day 4 visitor responses were gathered without any change from the usual presentation of the showrooms (no deliberate smell, or control day). In summary, this was the setup of the experiment, please refer to the methodology section for further details:

DAY 1	HISTORIC POT-POURRI + INFORMATION CARD
DAY 2	HISTORIC POT-POURRI + FACILITATOR
DAY 3	PERFUMED CONSERVATION WAX
DAY 4	CONTROL (SHOWROOMS AS USUAL)

Participants were asked about sensory engagement during the visit. The survey questions were designed to understand how visitors were engaged via different sensory modalities and elicit their attitudes towards the visit. In the first part of the questionnaire, they were asked to rate their impressions on multisensory stimuli, specifically on finding interesting reading and viewing material, sounds, scents and textures in the showrooms.

Four hypotheses were tested during the study:

1) The visibility / invisibility of the source of a heritage smell[1] affects smell perception in a historic house setting,

2) Visual information / labelling related to an olfactory display in a museum positively affects perception of the smell by visitors,

3) A facilitator presence offering to sample smell next to an exhibition display has an effect on the way smells are perceived/reported by the public,

4) Exhibition-goers who report perceiving interesting smells in an exhibition tend to find the show evokes autobiographical memories.

As a result, a total of 192 surveys were collected over 4 days. The sample size

[1] A smell with cultural value due to its connection to the space, be it historical, physical, etc. as detailed in Bembibre, C., & Strlič, M. (2017). Smell of heritage: A framework for the identification, analysis and archival of historic odours. *Heritage Science*, *5*(1). http://doi.org/10.1186/s40494-016-0114-1.

was considered to be 137,600, an average of the number of visitors to Knole in 2016 to 2018 (Ibbotson, 2019). This sample size had a 95% confidence level with a 7% confidence interval.

Results and discussion

In terms of visitors' profiles, of the 192 people surveyed there were 66% female and 31% male respondents and the vast majority (79.7%) were 60 years old or older (12% of respondents were between 45 and 59 years old, 4.2% were 30 to 44, 3.6% were 18 to 29).

Regarding frequency of visits to heritage sites, almost half of respondents (47.9%) reported visiting every few months, with 23.4% visiting monthly and 21.4% visiting once or twice a year.

Responding to a question about self-reported sensory impairment and other disabilities, 86.5% of respondents reported no disability, while just over 3% reported a hearing condition that prevented them from hearing what is said in normal conversation even with a hearing aid; 1.6% reported an eyesight condition that prevented them from reading a newspaper even when wearing glasses or contacts, 2.1% reported a condition that substantially limited their perception of smells, 5.7% reported having another physical disability and 1% reported an emotional or mental disability.

A few other relevant pieces of information were considered when interpreting the results:

a) Grass pollen levels were at a 12-year high during part of the experiment (Hosie, 2018). For people suffering pollen allergy, this implies an affected or even (temporarily) lost sense of smell.

b) Since almost 80% respondents identified themselves as '60 years or older', it was taken into account that an impaired sense of smell might be more prevalent

in this age group, evidenced by a decreased ability for odour identification, discrimination and detection of odour threshold, especially after 65 years of age (Hummel *et al.*, 1997).

c) Although olfactory identification abilities decrease with age as stated above, there is some recent evidence on the increased enjoyment on smells by perception of higher olfactory pleasantness increasing from age 50 onwards (Markovic *et al.*, 2007).

d) On average, women outperform men on tests of odour identification, detection, discrimination, and memory (Hawkes and Doty, 2009). This was considered as over 60% of the respondents were women.

d) It has been shown that older adults can lack awareness of olfactory dysfunction, limiting the accuracy of the self-reporting aspect (Adams *et al.*, 2017).

Responses to visual stimuli question were majorly positive. Most respondents thought there were interesting things to see and read on all four days of experiment, with an average of all answers between the ‘I agree’ and ‘I strongly agree’ options. Similarly, most respondents thought there were many interesting textures in the showrooms, with the majority of answers falling close to the ‘I agree’ option (Fig.11-3). Interestingly, although there was no option for further comments from the respondents on the questionnaires, the question about the textures elicited several written and verbal comments relating disappointment because there was no opportunity to feel the textures by touch.

In order to compare sight with other modalities of perception, visitors were asked to rate agreement with two further statements on a four-point scale: a) there were interesting sounds and b) there were interesting smells. In contrast with the overall tone of the impressions about visual perception (‘there were interesting things to see/read’), where ratings were positive, the most frequently selected

statements regarding auditory and olfactory perception were largely negative ('I disagree', 'I strongly disagree'). In fact, this is true for all days of the experiment except for the session where the sample of potpourri was offered to the public to smell by an facilitator present in the showrooms (Day 2). In this case, as it can be seen in Fig.11-3, visitors who agreed that there were 'interesting things to smell' were in the majority.

Also worthy of note is the fact that the tendency to almost unanimous agreement with the visual statement on all days is in contrast with a variability of responses in regard to the non-visual sensory engagement statements (smells, audio, textures), which tended strongly towards the disagreement. Interestingly, the statement 'there were interesting textures' generated agreement (a mean of 0.97 across the four days of the study, very close to the 'I agree' rating, which was 1) in spite of visitors not being allowed to touch many of the interesting textures present in textiles and wood (there are ropes and glass panels separating aspects of the collection from visitors in several rooms). For this reason, answers to the texture statements could be considered also positive as part of the primarily visual priming observed in historic house visitors.

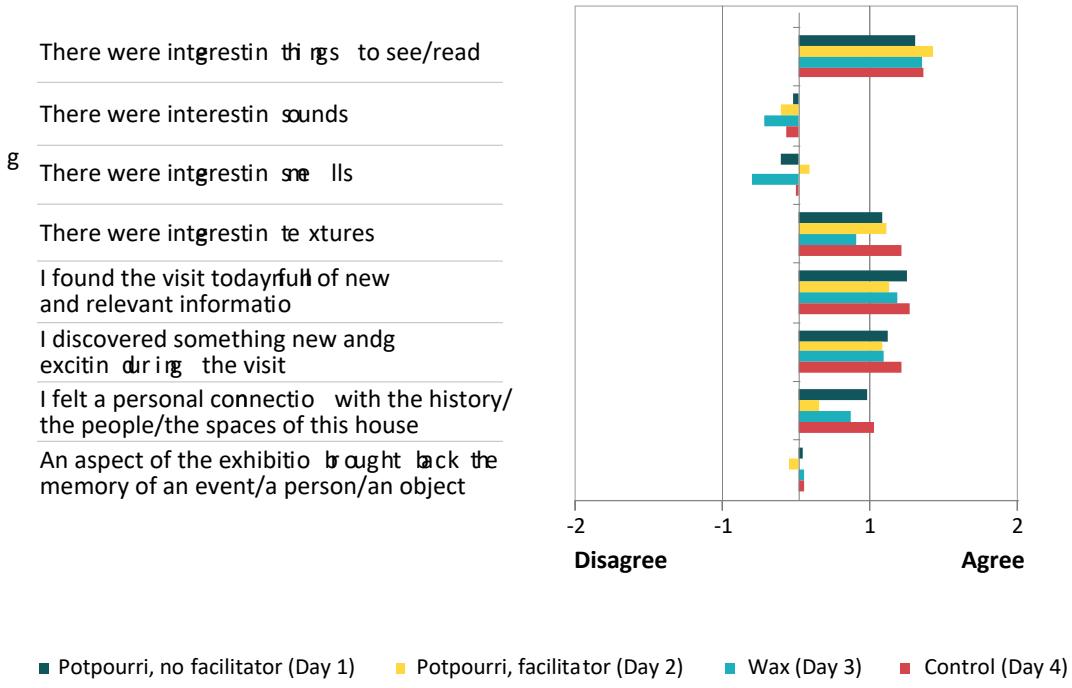


Figure 10-3. Average ratings to questionnaire statements (n=192). Key to olfactory stimuli as follows: Day 1=historic pot-pourri + information card, DAY 2=historic pot-pourri + facilitator, DAY 3=perfumed conservation wax, DAY 4=control.

A view of the same responses by gender shows that female respondents (68.3% of the total) followed the same overall trend in terms of their answers about sensory perception. The answers of male respondents (31.7% of total), however, show a slight difference of opinion: while most evaluations of the statements are similar (visual engagement rated positively, auditory and olfactory engagement rated mostly negative), just over 20% agreed with the statement 'I found interesting things to smell' on a day where no olfactory input had been deliberately set up (control day).

However, no statistically significant difference was found when comparing responses to the perception of interesting smells questions given by men and women (p=0.503 on a t-test comparing both sets of data).

Age was not a factor that divided visitors overall trends in responses: when grouped in two large categories, those under 60 (19.9%) and those over 60 (79.1%), results were very similar to the all respondents ones: visual perception with positive ratings, auditory and olfactory engagement with negative ratings except for the session with engagement via an facilitator in the showrooms (Day 2).

Looking at the four days of the experiment in detail, where visitors rated experience on a scale of +2 (I strongly agree) to -2 (I strongly disagree), the positive rating of visual engagement was slightly higher on the control day (Day 4, an average of 1.5 for seeing/reading and 1.25 for textures) and in the day the perfumed wax could be perceived (Day 3, averages of 1.5 and 1.2 respectively) than in the days where the potpourri display with the information card was present, be it on its own (average positive ratings for visual engagement of 1.4 and 1) or with the facilitator present (averages of 1.4 and 1.1). Ratings for auditory engagement were all negative, with averages ranging from -0.4 (on Day 3) to -

0.07 (on Day 2).

Ratings for the olfactory engagement statements ('There were interesting smells') were mostly negative, with averages of -0.57 (Day 3), -0.22 (Day 4) and -0.003 (Day 1). On the day the facilitator was present, however, the average rating for the same question was positive and responses were on average higher (Day 2, 0.58) than those to the same question on control day. The difference was not, however, statistically significant (p=0.21 in a proportion test). No statistically significant difference was found in responses to the statement 'There were interesting smells' on scented days and the control day (Day 1 p=0.40, Day 3 p=0.98).

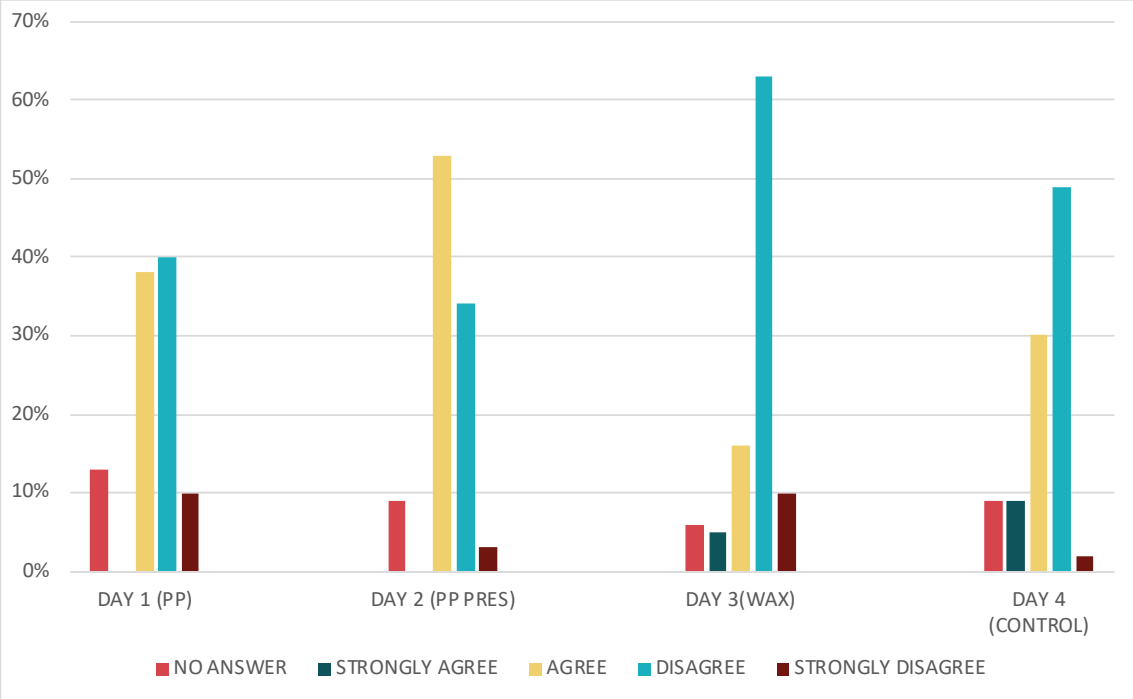


Figure 10-4. Ratings for the statement 'There were interesting smells' (in the exhibition). Key to olfactory stimuli as follows: DAY 1=historic pot-pourri + information card, DAY 2=historic pot-pourri + facilitator, DAY 3=perfumed conservation wax, DAY 4=control.

Comparing the day where the pot-pourri display was accompanied by an facilitator inviting to sample the smell (Day 2) with the day perfumed wax had been applied to the furniture and floors (Day 3), a significant difference was found in the average of people who responded positively to the statement 'There were interesting smells' (p=0.0006 for a proportion test of positive vs total responses),

as shown in Fig.11-4.

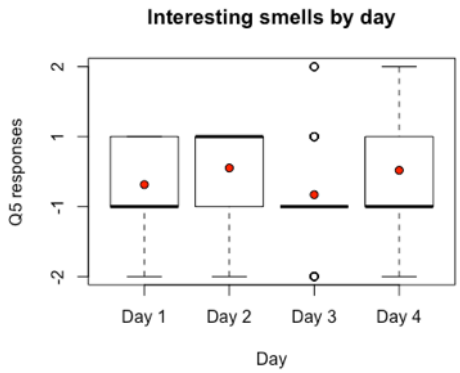


Figure 10-5. Patterns of ratings of the statement 'There were interesting smells' by day of the experiment. The dark black line in the box represents the median (mid-point of the data) and the red dot inside each box represents the mean (average).Key to olfactory stimuli as follows: Day 1=historic pot-pourri + information card, DAY 2=historic pot-pourri + facilitator, DAY 3=perfumed conservation wax, DAY 4=control.

The patterns of responses to the smell statement show that participants held similar opinions on Days 1 and 4 (with the median close to the 'disagree' option, an opinion shared by over 50% of respondents of Day 3 as well). Day 2 showed the biggest difference by comparison, where the median is close to the 'agree' option, making it the only day with this characteristic.

These findings may be somewhat limited by the high variability in the data (see error bars on Fig.11-5) regarding responses to the statement "There were interesting smells'.

Then, responses of people who reported they had perceived interesting smells on any of the days of the experiment where a deliberate scent had been introduced (both days of the pot-pourri, the day of the wax) were compared to their choices on whether:

a) they found the visit full of new and relevant information,

b) they discovered something new and exciting during the visit,

c) they felt a personal connection with the history / the people / the spaces of the house,

d) an aspect of the exhibition brought back the memory of an event/a person/an object of their past.

On average, people who agreed or strongly agreed with the statement ‘there were interesting smells’, also agreed to having found the visit full of new and relevant information (p=0.002), to having discovered something new and exciting during the visit (p=0.0006) and to having an aspect of the exhibition bring back the memory of an event/a person/an object of their past (p=0.002) but no significant relation was found between those who perceived interesting smells and those who responded positively to feeling a personal connection with the history / the people / the spaces of the house (Fig.11-4). In terms of sound perception, people who agreed on average with the statement ‘There were interesting sounds’ tended to respond positively to having found the visit full of new and relevant information (p=0.01), having discovered something new and exciting during the visit (p=0.0002), but no significant relation was found between those who perceived interesting sounds and those who responded positively to feeling a personal connection with the history / the people / the spaces of the house, or having an aspect of the exhibition bring back the memory of an event/a person/an object of their past.

Agreement with the statement ‘There were interesting textures’ correlated to the statement that the visit had been full of new and relevant information (p=0.004), but no statistically significant relation was found between positive responses to the texture statement and having discovered something new and exciting during the visit, feeling a personal connection with the history / the people / the spaces of the house, or having an aspect of the exhibition bring back the memory of an event/a person/an object of their past.

For comparison, strong correlations were found between answers of people who agreed with the statement ‘There were interesting things to see/read’ and those who responded positively to having found the visit full of new and relevant information (p=1.24e-05), having discovered something new and exciting during the visit (p=2.706e-06), feeling a personal connection with the history / the people / the spaces of the house (p=0.006) but no significant correlation was found

between them and those who reported having an aspect of the exhibition bring back the memory of an event/a person/an object of their past.

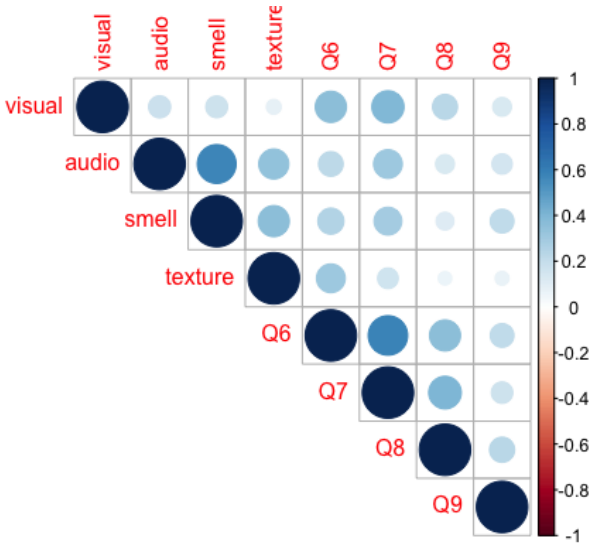


Figure 10-6. Correlations between participants' ratings to sensory engagement statements and ratings to questions 6 ('I found the visit full of new and relevant information'), 7 ('I discovered something new and exciting during the visit'), 8 ('I felt a personal connection with the history / the people / the spaces of the house') and 9 ('An aspect of the exhibition brought back the memory of an event/a person/an object of my past'). The bigger and darker the circle, the stronger the correlation.

The study found a marked (and expected) difference in the way visitors engaged with the visual and non-visual aspects of the exhibition. A general finding is that the tendency to agree with the presence of visual engagement, in comparison with the tendency to disagree with the presence of non-visual engagement over all days, highlights the strong visual conditioning of visitors to the showrooms.

Four key aspects from the research findings merit discussion:

- Perception of a heritage smell with a visible source and displayed with written information and an invitation to sample was significantly greater in self-reports than that of another heritage smell coming from an invisible source. The difference between average responses to this question on Day 2 (pot-pourri, visible source to the smell, with label and facilitator present) and Day 3 (perfumed wax, invisible source to the smell, no information given) was statistically significant and highlights the well-

recorded importance of non-olfactory cues, such as images or labels, in odour perception, which to our knowledge has not been tested until now in a historic house setting. The interactions between visual and olfactory stimuli have been proven especially significant in respect to some aspects such as odour and colour by previous research (Demattè, Sanabria and Spence, 2009). Furthermore, visual perception affects the way we process olfactory input, allowing even a discrepancy between self-reported intentions and actual olfactory and visual preferences (Yang and Chen, 2015). This finding is of special interest to atmospherics studies in museums, a field of growing interest as discussed in the introduction to this chapter, and the difference in the public's perception according to presentation mode of the smell might be useful to the interpretation of collections in heritage spaces, although ethical implications, such as those discussed in the introduction, require considerations.

- The presence of a facilitator next to the display resulted in the majority of respondents perceiving interesting smells in the showroom, against the overall trend of visitors disagreeing with the existence of interesting smells in the space on every other day. These findings may be limited by the lack of statistical significance, but further research should be undertaken to better understand this result, given their potential implications for exhibition design and public engagement. Another aspect worth researching further are the expectations of visitors in regards to non-visual cues in heritage exhibits, and how those expectations affect the perception of non-visual cues.

- Visitors who find interesting smells in an exhibition agree with the fact that an aspect of the exhibition brings back the memory of an event/a person/an object of their past. These results are consistent with published research on odour and memory, showing that odour-evoked memories are emotionally potent and related to autobiographical memory, associated with stronger feelings of being brought back in time compared to memories evoked by other sensory cues (Larsson and Willander, 2009), and can now add to our understanding of the impact of incorporating scented components into the narrative of a historic house exhibition.

- The consistency of positive ratings for visual engagement across all days of the study, coupled with the positive ratings achieved by the texture statements (even the engagement via touch was not a prominent feature in the showrooms, as previously discussed) evidence a bias towards sight in visitors, consistent with Western museum settings. It also evidences the enormous potential for non-visual engagement with the space and collections that could be fulfilled during the visit, which should be of interest to visitor experience designers and the heritage community as a whole.

10.3 Chapter summary

- A discussion on the nature of olfactory objects is taking place within the field of perception; this is relevant for aspects of heritage smells such as the visibility of the source, odour authorship and interpretation.
- The smell of perfumed conservation wax was characterised as a heritage smell, documenting it as a reminder that this product is used to care for furniture in what once was a domestic environment.
- A study on the value of olfactory input in Knole showed that other forms of sensory input, especially visual, account for most of the experience visitors are aware and self-report for after a tour of a historic house. The conditioning of sight as the privilege sense, discussed in the Smell and heritage chapter, plays an important role here.
- The presentation of a smell with a visible source and an invitation to sample was reported as perceived by significantly more visitors, showing the importance of contextualising historic odours and assisting their interpretation by the public in a way that highlights the smell significance and relates it to other aspects of heritage such as historic practices and heritage buildings. Perceiving a historic smell resulted in many visitors reporting autobiographical memories. This provides a powerful opportunity for thinking about heritage narratives in a more emotional way, using smell as a way in.
- The unrealised potential for non-visual engagement with heritage spaces and collections, as evidenced by this study, might be part of a bigger trend, and further studies are needed to better understand how generalizable these findings are. However, these conclusions already increase our understanding of the value of odours visitors experience of historic houses and therefore should be of interest to visitor experience designers and the heritage community.

11 A musty odour. Characterisation of the smell of mould and study on context-dependant odour perception

The variety of case study odours addressed in the previous chapters (old book and library, perfumed conservation wax, historic pot-pourri) have in common that they are, as I have shown, generally positively perceived. People tend to like these smells, or at least evaluate them as neutral to pleasant. In order to explore a series of theoretical and practical aspects of heritage smells, this chapter deals with an ambiguous odour and explores its perception in terms of hedonic tone, familiarity and safety. Moreover, the role of semantic labels is also discussed as part of the study results.

Cognitive evaluation (non-sensory perception) is considered as important as sensory reception in the individual perception of an odour. Previous studies report that environmental conditions and individual expectations play an important role in characterising a smell. For example, odours with positive names are, in general, evaluated as more pleasant, more familiar, and safer than negative ones (R S Herz, 2003).

One of the ways odour perception is affected is by semantic labelling of smells. In one experiment, an odorant (iso-valeric acid + butyric acid) was presented with two hedonically different labels (parmesan cheese as positive and vomit as negative), leading to different characterisations and ratings of hedonic evaluation (Herz and Clef, 2001). Verbal priming, which allows perception manipulation, has also been shown by Herz et al to work better with some odours ('ambiguous') than others. In addition to the role of semantic labels on hedonic tone evaluations, the familiarity with an odour also has an impact on its characterisation. There is evidence that unfamiliar odours tend to be evaluated as unpleasant (Engen, 1991), and a positive correlation between familiarity and pleasantness has been observed in everyday odours (Distel, 1999). Once a smell has been given a label, it can be regarded as less unfamiliar (Ayabe-Kanamura *et al.*, 1998).

Cognitive bias can also affect the perception of safety of an odour. For example, when information about the odorous compounds' risk to health have been shared

before people smell a sample, reports of the irritant effects are correlated with expectations even if the irritant is removed and only the odour is present (Dalton *et al.*, 1997). In another experiment, two groups of participants were asked to rate the same set of nine odours from the healthiest to the most hazardous to health (group 1), and vice versa (group 2), in the context of choosing odours to highlight healthy or dangerous groups of chemicals. Some odours were consistently rated as healthy or hazardous by both groups, but some of them were rated as healthy by one group and hazardous by the other, leading the facilitators to highlight the role of the instructions in the sensory evaluations. This effect is significant given the correlation between perceived risk of exposure to an odorant and odour annoyance (Dalton, 1996). Sensory components can also affect evaluation. For example, fresh-scented bleach is considered less dangerous than non-scented version of the same product (De Wijk and Cain, 1994).

In addition, when the source of an odour is presented as natural or synthetic, both hedonic tone and safety evaluations are affected. Odours identified from a natural source tend to be evaluated as more pleasant and safer than synthetic odours (Rachel S. Herz, 2003). As a precedent for the ambiguity of the mould-like odours that made them suitable for this study, a green, earthy odour presented with the hedonically different labels of ‘mildew’ (negative) and ‘fresh cucumber’ (positive) was perceived as two different smells by 88% of the evaluators (Herz and Clef, 2001).

In this chapter, I characterise and document the smell of mould, identifying opportunities for new associations in the context of heritage practice and engagement.

11.1 Mould experiment results & discussion

11.1.1 Significance assessment

Mould and mildew are used to describe a fluffy growth on a surface or, more specifically, for the small furry growths with a black centre commonly found on organic matter. The smell of mould has long been associated with the activities

of the historian and the conservator. In *On the Uses and Disadvantages of History for Life*, Nietzsche alerts of the perils of the 'mouldy smell' that can envelop the antiquarian in his engagement with history. It has been interpreted that this smell stands for the moment when "the capacity of the past to offer a source of renewal to the present tips over into a suffocating persistence, a perverse taste for haut goût, that which is dead and rotten, and the image of the antiquarian as necrophiliac" (Beata Labuhn, 2017).

The progress of mould, from the initial growth to the total colonization of a surface could be seen as 'matter out of place' in the sense proposed by Mary Douglas for dust. "In the course of any imposition of order, whether in the mind or in the external world, the attitude to rejected bits and pieces goes through two stages. First, they are recognisably out of place, a threat to good order, and so are regarded as objectionable and vigorously brushed away. At this stage they have some identity: they can be seen to be unwanted bits of whatever it was they came from (…). This is the stage at which they are dangerous; their half identity still clings to them and the clarity of the scene in which they obtrude is impaired by their presence" (Douglas, 1966).

This is how mould is usually first discovered, as a spreading threat on a treasured surface. There are still two clearly recognisable forms, the object and the invader. This is, according to Douglas' reasoning, the dangerous stage. Once mould has ruined, colonised, taken over, the artefact has disappeared. The differentiation is gone, the threat is no longer there.

When ambiguous scenarios are presented in heritage, the conservative approach is to neutralise them by categorising them, for example, as artefacts or as waste. A different strategy has been proposed by Dawdy (2018), who considers a way to deal with these scenarios "that understands the artefact as a process, rather than a stable entity with a durable physical form". If smells could be also understood as part of a process (often a reflection of the process of material change undergone by the source), this would allow for new interpretations and narratives, ones capable of working with the ambiguities.

Recognising the smell of damp, and understanding its implications, is essential to professionals working in a historic house because they can identify the risk in

its beginning. Mentions to the smell of mould in a conservation manual are both evocative in their warning (“In the damper air mould can thrive and metals corrode. You only have to think of the damp smell of the holiday cottage that has been left unheated all through the winter”) and alerting of a health risk: “high RH identified by a ‘damp’ smell is the nose detecting spores from moulds and fungi” (The National Trust, 2006). The name ‘Damp Room’ for one of the samples in the study discussed in this chapter connects directly with this aspect of mould.

Mould can be seen as a symbol of deterioration and decay. It grows on surfaces that have been forgotten, out of sight, abandoned by the housekeeper. We have a hard-wired response to mould: in the context of human food -with some exceptions such as blue cheese, which we learn to like through cultural inheritance (Herz, 2012)-, it elicits disgust; it is associated with spoilage and contamination. In a picture scale where images are used to induce disgust, for example, the picture of a mouldy tomato caused more disgust than images showing meat and fish in conditions of poor hygiene (Ammann, Hartmann and Siegrist, 2018). The furry invasion brings nature into buildings and reminds us all that we are just temporary. “I've always been fascinated by old ruined buildings, but I suddenly started to think about how to reproduce in small scale the particular sensation of being in a lonely, abandoned place”. Explains artist Daniele del Nero, who creates architectural scale models of buildings, dampens the exterior of the structure and applies a thin dusting of flour. Mould starts to grow after a couple of days, and he photographs the models then (Fig.12-1). “We are used to imagining our cities as permanent and definitive, but it's amazing how little time it takes for nature to reclaim its spaces” (Solon. O., 2010).

Figure 11-1. Image from the After Effects series by artist Daniele del Nero. ©Daniele del Nero.

In nature, the smell of a forest in the autumn is one appreciated by many, and widely discussed on internet forums. Described as “damp earth combined with old fallen leaves. This earthy smell has an instinctive calming effect to a human” (The everyday adventurer, 2009) and “the air smells crisp and cold some days, and damp and more earthy on other days, depending on the weather” (Bateman, 2016). Unlike the reaction to mould in buildings, the presence of mould in the outdoors seems to be tolerated in view of the positive role it has: “though in our homes mould may be a mischief, it is a friend and partner to the environment. Mould and fungi found in your garden are an important component of healthy soil and plant growth. Beneath layers of dead leaves, grass, and straw lie miles and miles of mycelial colonies in the soil” (PermacultureResearchInstitute, 2016). In the study conducted in this chapter, and aiming to evoke a different context where mould would naturally grow in a historic house, where visitors might encounter the smell, the label ‘Autumn Forest’ was chosen to explore the positive connotations of the sample odours.

11.1.2 Chemical analysis

The air around mould located inside the drawers of a chest in a historic church was sampled using carbon-sorbent tubes connected to an air pump (see Fig.12-2 below and methodology chapter for details).

Over 150 volatile organic compounds were found in the sample, in 48 min of analysis, with the highest density of peaks between 18 and 38 min.

The most abundant compounds are shown in Tab.12-1; together they account for just over 50% of the sample volume. In the case of this sample, although the sampled volume (10L) was consistent with industry practice standards, compounds were present in low concentrations. It is assumed that a higher-volume sample would allow for detection of additional compounds that could add sensory nuance. This would apply especially if they had a low odour threshold that made them detectable by the human nose in small quantities, since a higher concentration of a compound does not necessarily make it detectable by the human nose. A higher volume sample would also allow for characterisation of the MVOCs, which was not attempted in this case but can reportedly be achieved with sample volumes of 20-30L (Wilkins et al., 1997).

Compound	CAS No.	Chemical group
α-Pinene	80-56-8	Terpenes
Cyclofenchene	488-97-1	Terpenes
C_6H_6	10420-90-3	Aliphatic Hydrocarbons
Pentane, 2-methyl-	107-83-5	Aliphatic Hydrocarbons
Isobutane	75-28-5	Aliphatic Hydrocarbons
Toluene	108-88-3	Aromatic compounds
p-Xylene	106-42-3	Aromatic compounds
Ethanol	64-17-5	Alcohols
Methyl Alcohol	67-56-1	Alcohols
Pentane, 3-methyl-	96-14-0	Aliphatic Hydrocarbons
Pentane	109-66-0	Aliphatic Hydrocarbons
d-Limonene	5989-27-5	Terpenes
Isopropyl Alcohol	67-63-0	Alcohols
n-Hexane	110-54-3	Aliphatic Hydrocarbons
Oxalic acid	144-62-7	Organic Acids
Undecane	1120-21-4	Aliphatic Hydrocarbons
Benzene, 1,2,3-trimethyl-	526-73-8	Aromatic compounds

Table 11-1. Compounds with highest abundance in the sample, as identified by GC-MS-ToF analysis. This set of compounds account for just over 50% of the sample.

11.1.3 Sensory analysis

GC-Sniffing

A total of 23 odours were confirmed by two or more analysts. A percentage (around 60%) of those smells were correlated to chemical compounds present in the sample, as can be seen in Tab.12-2. Accuracy in the identification of odour-active compounds using GC-O may be affected by the high number of co-elutions that can occur during analysis (d'Acampora Zellner *et al.*, 2008) and the fact that the human nose is more sensitive than most GC detectors for certain odour compounds (Acree, 1994).

Pungent, earthy, green odours predominated, as expected, with the highest frequency occurring between 22 and 40 min.
In terms of hedonic tone, most of the odours were perceived as pleasant or neutral by the analysts.

T1	Intensity	Descriptors GC-O	Published descriptors	Compound	CAS
10.13	1	*pungent, herbal, fatty,*	earthy alcoholic winey	Propanal	123-38-6
13.5	2	*flowery,*	hyacinth foliage green	2-Methyl, 2-propenal	78-85-3
13.98	2	*pungent, fatty,*	n/a	n/a	n/a
15.06	2	*unpleasant, earthy,*	n/a	n/a	n/a
n/a	1	*sweet,*	acetone ethereal fruity	2-Butanone	78-93-3
19.5	1	*green, fermented,*	green fusel oily	2-Pentanol	6032-29-7
22.75	2	*paint, solvent, fresh,*	sweet, paint	Toluene	108-88-3
25.18	2	*pleasant,*	minty	Cyclopentanone*	120-92-3
28.38	2	*fresh, green, sweet,*	green fatty fruity	3-Heptanone	106-35-4
29.6	2	*fresh, green,*	fresh camphoreous	α-Pinene	80-56-8
30.86	2	*mushroom,*	n/a	n/a	n/a
31.6	1	*woody, fresh, resinous,*	sharp, terpenic, conifers,	(-)-β-Pinene	18172-67-3
32.5	1	*flowery, pungent,*	n/a**	Cyclofenchene	488-97-1
35.13	1	*creamy, dry-leave, dry,*	n/a	n/a	n/a
35.66	1	*sweet, dry-leave,*	n/a	n/a	n/a
37.6	1	*musk, dry-leave,*	n/a	n/a	n/a
39.25	3	*camphor, medicinal,*	camphoreous	Camphor	76-22-2
39.33	2	*fatty, oily, citric,*	fatty waxy rancid oily	Octanoic acid	124-07-2
40	2	*woody, fresh, resinous,*	sweet, fresh, piney	Terpinolene	586-62-9
44.06	2	*mint, camphor,*	n/a	n/a	n/a
45.45	3	*earthy, mushroom,*	n/a	n/a	n/a
46.76	1	*cardboard, paper,*	n/a	n/a	n/a
47.33	2	*camphor, woody,*	floral, fruity, fatty,	5,9-Undecadien-2-	3796-70-1

Table 11-2. Odours registered during GC-O analysis of the sample. T1 indicates the time the analyst first perceived the smell. The asterisk (*) next to a compound name indicates that it was not possible to fully validate the identification and (**) indicates that no odour descriptor was found. Referenced descriptors are from Flavornet, Mosciano and VCF databases.

In order to contextualise the identified compounds, propanal (CAS 123-38-6) is a flavouring agent used in baked and frozen goods; also as a disinfectant and preservative. 2- methylpropenal (CAS 78-85-3) is used to manufacture polymers and synthetic resins; it occurs naturally in the plant sagebrush (*Artemisia tridentata*) and in cigarette smoke. 2-Butanone (CAS 78-93-3) is an odorant that has a number of natural sources, such as truffles and butter, and also occurs in cooked mushrooms (Schreiner, Bauer and Buettner, 2018). 2-Pentanol (CAS 6032-29-7) occurs naturally in fresh bananas (Jordán *et al.*, 2001), and is used as a solvent. Toluene (CAS 108-88-3) is used as a solvent primarily, and occurs naturally in many plant and herb oils, including petitgrain and dill. Cyclopentanone (CAS 120-92-3) is used as a fragrance ingredient, especially in jasmine-containing scents. It occurs naturally in coffee aroma and lavender oil. 3-Heptanone (CAS 106-35-4) is used to add a sweet note to fragrances, and in flavouring to impart a melon, nut, and banana flavour. α-Pinene (CAS 80-56-8) and (-)-β-Pinene (CAS 18172-67-3) are used in the flavour and fragrance industry. Naturally, they are both important constituents of pine resin and found in the resins of other conifers. Cyclofenchene (CAS 488-97-1) is a monoterpene that occurs naturally in *Salvia tormentosa* and eucalyptus oil. Camphor (CAS 76-22-2) is used to manufacture chemicals and plastics, also as a medicine, antiseptic and insecticide. Octanoic acid (CAS 124-07-2), also known as caprylic acid is used in perfumery and a variety of other products including synthetic lubricants, amides, plasticizers, flavour compounds, perfumes, antiseptics and fungicides. Terpinolene (CAS 586-62-9) is used in perfumery; it occurs naturally in cypress cone oild, bergamot oil and a number of other sources. 5,9-Undecadien-2-one, 6,10-dimethyl-, (E) (CAS 3796-70-1), also known as geranyl acetone. It is a component of essential oils from various plants including Indian lotus (*Nelumbo nucifera*). It has a role as a flavouring agent, a fragrance, a volatile oil component and a plant metabolite.

Figure 11-2. Wordcloud featuring the most frequent descriptors for the odours detected by GC-O. Descriptors were multiplied by intensity to offer a more accurate representation of the sensory profile.

Panel evaluation

In order to conduct sensory characterisation, three reconstructions of the mould smell were prepared in the laboratory and labelled sample 1, 2 and 3. These three versions of the scent contained different mixtures of the representative compounds identified in the literature (Vázquez-Araújo, Chambers and Funk, 2011; Lappalainen *et al.*, 2015; Sawoszczuk and Syguła-Cholewińska, 2017) and the analysis. The compounds were:

Compound	CAS	Odour description	Preparation in DPG
Furfural	98-01-1	bread, almond, sweet	10.00%
α-pinene	7785-26-4	pine	5.00%
1-octen-3-ol	3391-86-4	mushroom earthy green oily fungal raw chicken	10.00%
3-carene	13466-78-9	sweet citrus terpenic fir needle	10.00%
Geosmin	16423-19-1	beet, earth	1.00%
3-octanone	106-68-3	fresh herbal lavender sweet mushroom	10.00%

Table 11-3. Volatile organic compounds (VOC) representative of mould odour and the concentrations used in the smell reconstructions. Referenced descriptors are from Flavornet and VCF databases.

The first sample (sample 1) contained 3-octanone, 1-octen-3-ol and geosmin. The second sample (sample 2) contained 3-carene, furfural and pinene. The third sample (sample 3) contained pinene, 1-octen-3-ol and geosmin. They were prepared mixing the identified odorants into dipropylene glycol (see methodology section for details).

Each sample (1, 2 and 3) was then given three labels: a neutral one (A), a positive one (Autumn Forest) and a negative one (Damp Room). In other words, A1, Autumn Forest 1 and Damp Room 1 corresponded to the same smell (sample 1), A2, Autumn Forest 2 and Damp Room 2 also corresponded to the same smell (sample 2, which was an odour different to sample 1), and so on. In summary, the study was carried out using three different smells, each presented with three unique labels (neutral, positive and negative).

Sample	Compounds in the mixture	Solvent	Labels
SAMPLE 1	3-octanone 1-octen-3-ol Geosmin	Dipropylene glycol (DPG) CAS 25265-71-8	A1 AUTUMN FOREST 1 DAMP ROOM 1
SAMPLE 2	3-carene Furfural α-pinene	Dipropylene glycol (DPG) CAS 25265-71-8	A2 AUTUMN FOREST 2 DAMP ROOM 2
SAMPLE 3	α-pinene 1-octen-3-ol Geosmin	Dipropylene glycol (DPG) CAS 25265-71-8	A3 AUTUMN FOREST 3 DAMP ROOM 3

Table 11-4. Reconstructions of the smell of mould: composition, and labels for each of the samples as presented for sensory evaluation.

The sensory tests aimed to explore several aspects of the smell of mould:

1) Does the ambiguity of this smell recorded in previous studies (Herz and Von Clef, 2001) hold true using positive, negative and neutral labels?

2) Are evaluations of hedonic tone via pleasantness scales and polarity profile similar? Are these affected by labels?

3) What aspects of this analysis can be interpreted in connection to the smell of mould in heritage objects and spaces?

One part of the sensory test required participants to choose a set of relevant descriptors for each uniquely labelled smell, from a list of 33 words, selected from the GC-O analysis (see Appendix III).

Within sample 1, vials labelled as A1 were attributed 'mushroom', 'fungus', 'earth', 'damp' and 'decay' as main descriptors. In this case, the three main descriptors were chosen by 20-23% of participants each. Vials labelled Autumn Forest 1 were attributed 'mushroom', 'damp', 'woody', 'fungus' and 'earth' as main descriptors. 'Mushroom', the main descriptor, was chosen by 53.3% of participants. Vials labelled Damp Room 1 were attributed 'damp', 'mushroom', 'wet leaves', 'fungus' and sweet' as main descriptors. In this case, 'damp', the main descriptor, was chosen by 53.3% of participants. However, getting past the main descriptors, the characterisation for the smell changed with the label, featuring descriptors uniquely chosen in each case, such as ‘decomposed’ for A1, ‘raw chicken’ for Autumn Forest 1 and ‘resin’ and ‘dust for Damp Room 2 (Fig 11-4, see Appendix III for a larger version of this graphic).

Within sample 2, vials labelled as A2 were attributed 'almond', 'sweet', 'fresh' and 'lemon' as main descriptors. The two main descriptors were chosen by 33% and 22% of participants, respectively. Vials labelled Autumn Forest 2 were attributed 'almond', 'fresh' and 'sweet' as main descriptors. 'Almond’ was selected by 27% of participants, while the next two most frequent descriptors were selected by 13% each. Vials labelled Damp Room 2 were attributed 'almond', 'sweet' and 'lemon' as main descriptors. The two main descriptors were chosen by 22% of participants each. However, getting past the main descriptors, the characterisation for the smell changes with the label, featuring descriptors uniquely chosen in each case, such as ‘bread’ for A2, ‘acetone’ and ‘plastic’ for Autumn Forest 2 and ‘resin’ and ‘wet leaves’ for Damp Room 2 (Fig 12-4, see Appendix III for a larger version of this graphic).

Sample 1

Sample 2

Sample 3

Figure 11-3**.** Odour quality descriptions from panel evaluation (total n=15) of each uniquely-labelled scent in sample 1 (A1, Autumn Forest 1 and Damp Room 1), sample 2 (A2, Autumn Forest 2 and Damp Room 2) and sample 3 (A3, Autumn Forest 3 and Damp Room 3). Area size correlates with frequency of use of the descriptor during the study and each colour corresponds to the same descriptor in all cases. These charts are included to give a colour-based overview; for a bigger version of this graphic with legible descriptors, please see Appendix III.

Within sample 3, vials labelled as A3 were attributed 'damp', 'mushroom' and 'earth' as main descriptors. The two main descriptors were chosen by 26% and 20% of participants, respectively. Vials labelled Autumn Forest 3 were attributed 'earth', 'mushroom', 'damp' and 'woody' as main descriptors. The two main descriptors were chosen by 26% and 20% of participants, respectively. Finally, vials labelled Damp Room 3 were attributed 'mushroom', 'damp' and 'fungus' as

main descriptors. The two main descriptors were chosen by 41% and 23% of participants, respectively. However, getting past the main descriptors, the characterisation for the smell changes with the label, featuring descriptors uniquely chosen in each case, such as ‘lemon’ and ‘beetroot’ for A3, and ‘tree bark’ and ‘sweet’ for Autumn Forest 3 and Damp Room 3 (Fig 12-4, see Appendix III for a larger version of this graphic).

Each of the three distinct mould smell reconstructions was characterised using the same set of 3 main odour descriptors, which were agreed by around half of participants in each case. This can be clearly seen in the colour-coded graphic, where all three charts for each sample share a very similar colour scheme. The secondary quality descriptors chosen varied with the label. A possible explanation for these results is that descriptors of odour quality are primarily influenced by the olfactory stimuli, and secondarily by the non-olfactory information (labels).

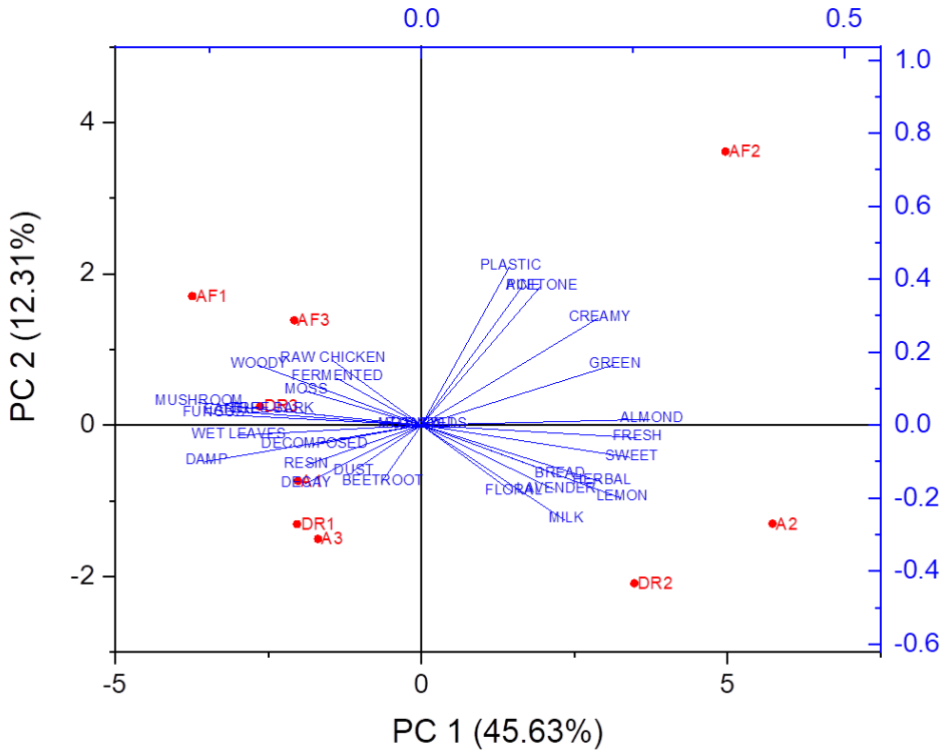


Figure 11-4. Principal component analysis (PCA) plot showing how odour descriptors influence each of the mould odour samples and labels. x axis=PC1 score, y axis=PC2 score.

When principal component analysis is applied to the data, the emerging trends confirm that each sample is influenced differently by odour descriptors, with sample 2 being the most different to the other two in terms of quality characterisation (Fig.12-4). This analysis also shows a distinction between the descriptors used in the sample that was evaluated as pleasant (sample 2, on the right side of the plot), as I will discuss later, versus the ones that were evaluated as unpleasant (samples 1 and 3, on the left side). Neutral, positive or negative labelling is not seen to have an impact into this main distinction. The labels do affect the descriptors in a different, although less dramatic, way: the positive label Autumn Forest for all samples can be found at the two top quadrants in the plot and the neutral (A) and negative labels (Damp Room) at the bottom two quadrants (with an exception, Damp Room 3, which is close to the limit between two quadrants).

The impact of semantic labels on odour quality characterisation is limited, in the sense that it does not affect the choice of few first descriptors from a given list. It does have an impact, as shown, on the contributions of those descriptors to the overall quality, and on secondary descriptors. Furthermore, the positive labelling of the smell, in the context of an autumn forest, conjured related descriptors that were not chosen when the sample was negatively or neutrally labelled. This presents an opportunity to explore new associations of a smell which is, as evidenced in the significance section, tradicionally linked to decay, decomposition and conservation risk.

The panel also reported on odour familiarity, safety and hedonic tone. With regards to familiarity, participants showed most agreement in their evaluations of smells AF2, AF3 and DR2 (Fig.12-6). The evaluation of sample 1 (A1, AF1, DR1) was very varied: A1 was mostly evaluated negatively (40% of participants rated it mildly unfamiliar and 13% moderately unfamiliar), Autumn Forest 1 mostly familiar (86% in total, with 14% finding it very familiar, 43% familiar and 29% mildly familiar) and Damp Room 1 also mostly familiar (64% in total). A1 and Damp Room 1 were considered neutral odours in terms of familiarity by similar

percentages of participants (around 14%) and Autumn Forest 1 was not considered neutral by anyone. A1 was considered the most unfamiliar of the three labels (53%), followed by Damp Room 1(21%) and Autumn Forest 1 (14%). Sample 2 was considered mostly familiar across all labels: A2=92% positive, Autumn Forest 2=100% positive and Damp Room 2=87% positive. As with the first sample, A2 and Damp Room 2 were considered neutral odours in terms of familiarity by similar percentages of participants (8 and 7% respectively) and Autumn Forest 2 was not considered neutral by anyone. No participants considered this sample unfamiliar with the labels A2 and Autumn Forest 2, but 7% rated Damp Room 2 as mildly unfamiliar (see Appendix III for barcharts of this study).

Like Sample 1, Sample 3 was evaluated differently depending on the labels: A3 was rated mostly neutral or unfamiliar in terms of familiarity (40% and 30% respectively), while Autumn Forest 3 and Damp Room 3 were rated mostly familiar (87% and 80%, respectively).

Some observations across samples:

Samples with the neutral label (A1, A2, A3) were rated as the least familiar.

Samples with the positive label (Autumn Forest 1,2,3) were rated as the most familiar.

None of the samples were considered very unfamiliar.

The sample considered the most familiar was the one evaluated as most pleasant.

The sample considered the most unfamiliar was also considered the most unpleasant.

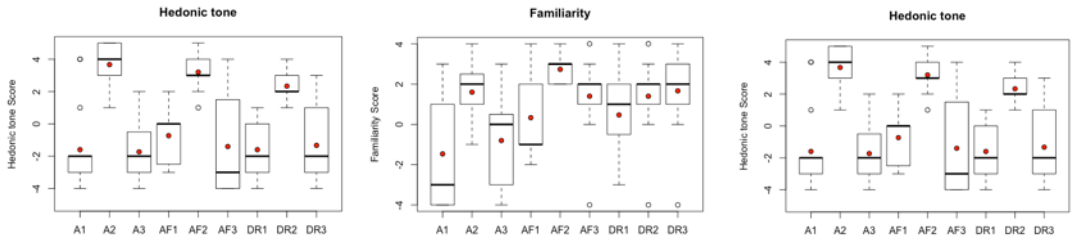


Figure 11-5. Distribution of familiarity, safety and hedonic tone data from panel evaluation (total n of panellists for all experiment=15). Participants were asked to rate three reconstructions of mould odour (samples 1,2 and 3), each with three different labels (A, Autumn Forest and Damp Room). The black line in the middle of the box represents the median (mid-point of the data) and the red dot inside each box represents the mean (average).These boxplots give an overview of results; for detailed barcharts of this study please see Appendix III.

The study also measured the perception of safety on all samples. Sample 1 had varied results, depending on the label (Fig.12-6) However, all samples were mostly considered as unsafe to some degree: 80% for A1, 67% for Autumn Forest 1 and 57% for Damp Room 1. Autumn Forest was considered the safest, with 33% of participants deeming it either 'safe' or 'mildly safe'. No sample 1 was evaluated as 'very safe'.

Sample 2 was considered mostly safe across all labels: A2 and Autumn Forest 2 were both considered safe in different degrees by 93% of participants, while Damp Room 2 was considered safe in some degree by 73% of respondents. Label Damp Room 2 was considered the most neutrally safe odour in this set, with 27% of respondents agreeing. There were no negative valuations for this odour in terms of safety.

Most of Sample 3 safety valuations were negative, although with differences among labels: 73% for A3, 60% for Damp Room 3 and 40% for Autumn Forest 3. There was a high percentage of respondents who considered this odour as neutral in regard to safety: 40% for Autumn Forest 3, and 20% for both A3 and Damp Room 3. The odour was considered safe by 20% of participants when it was labelled Autumn Forest 3 and Damp Room 3, but only 7% thought A3 was a safe smell. Regardless of labels, this sample was not considered very safe nor very dangerous by any respondents.
Some observations across samples:

- Label A was rated as the least safe of the 3.
- Label Autumn Forest was rated as the safest.
- Label Damp Room was considered the most neutral in terms of safety.
- Most of the ratings were in the 'moderately safe' to 'moderately unsafe' range.
- The only samples that received a percentage of 'very safe' evaluations corresponded to the ones also considered the most pleasant (sample 2).
- Following on this last observation, and comparing distribution for familiarity, safety and hedonic tone, it can be easily observed that the first one has a different distribution from the other two, both in median and mean (Fig.12-7). A relation between the variables of hedonic tone and safety can therefore be assumed, as previous studies have shown (De Wijk and Cain, 1994).

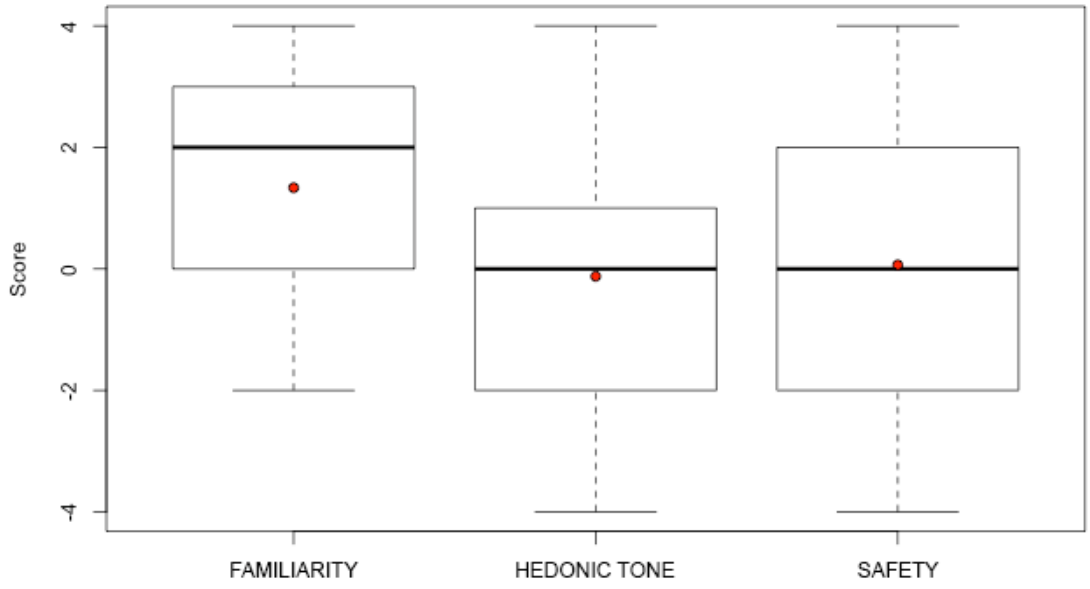


Figure 11-6. Boxplot showing the distribution of sensory evaluation data for familiarity, hedonic tone and safety of the mould reconstruction samples. The black line in the middle of the box represents the median (mid-point of the data) and the red dot inside each box represents the mean (average).

In terms of hedonic tone evaluated using Likert-style scales, Sample 1 (Fig.12-6) received mostly negative ratings (mildly unpleasant to very unpleasant) across all three labels: A1=80% negative, Autumn Forest 1=71% negative and Damp Room 1=73% negative. This sample was evaluated as neutral by 7% of participants when labelled A1, by 14% of participants with labelled Autumn Forest 1 and by 27% of participants when labelled Damp Room 1. It was rated positive as A1 (13% considered either mildly pleasant, moderately pleasant or pleasant) and Autumn Forest 1, but not when labelled as Damp Room 1.

Sample 2 received mostly positive ratings (mildly pleasant to very pleasant) across all three labels: A2=87% positive, Autumn Forest 2=93% positive and Damp Room 2=87% positive. This sample was evaluated as neutral by 13% of participants when labelled A2, by 7% of participants with labelled Autumn Forest 2 and by 13% of participants when labelled Damp Room 2. It had no negative ratings.

Like Sample 1, Sample 3 received mostly negative ratings across all three labels: A3 and Autumn Forest 3 both=73% negative and Damp Room 3=67% negative. This sample was evaluated as neutral by between 13 and 20% of participants across labels and had the lowest positive ratings at 7% for A3 and 13% for both Autumn Forest 3 and Damp Room 3 (these were only as mildly and moderately pleasant).

Some observations across samples:

- Label Autumn Forest was rated more pleasant and less unpleasant than the other 2.
- Label Autumn Forest was rated as less neutral than the other 2.
- Label Damp Room was rated more neutral than the other two.
- Label Damp Room was not rated very pleasant by any participant.

As a summary, samples 1 and 3 were evaluated as unpleasant and sample 2 as pleasant. Positive labels influenced the evaluation towards pleasantness, while

negative labels did so towards unpleasantness. Odours with neutral levels were evaluated, on average, closer to negatively-labelled smells.

The hedonic tone of the mould smells was also evaluated with the technique of polarity profiles, a previously described technique (see methodology section in for details). According to the standard, for an odour to qualify as hedonically definitely pleasant, the correlation between the profile of the odour and the representative fragrance and stench profiles has to be greater than 0.5 and less than -0.5, respectively (the normative focuses on facility odours).

Sample 1 was strongly correlated with the reference stench profile (n=0.9) and negatively correlated with the reference scent profile (n=-0.78). The overall trend was also true for all three labels for this odour, with different degrees of strength: A1 had a slightly weaker correlation with the stench profile (n=0.79) and also a weaker negative correlation with the scent profile (n=-0.67). Autumn Forest 1 showed a strong correlation with the stench profile (n=0.88) and a negative one with the scent profile (n=-0.75). Finally, Damp Room 1 was the label for this sample most closely correlated to stench (n=0.92) and negatively correlated to scent (n=-0.81). Sample 1 can therefore be evaluated as hedonically unpleasant, according to the guidelines (Deutsches Institut fur Normung E.V. (DIN), 2010).

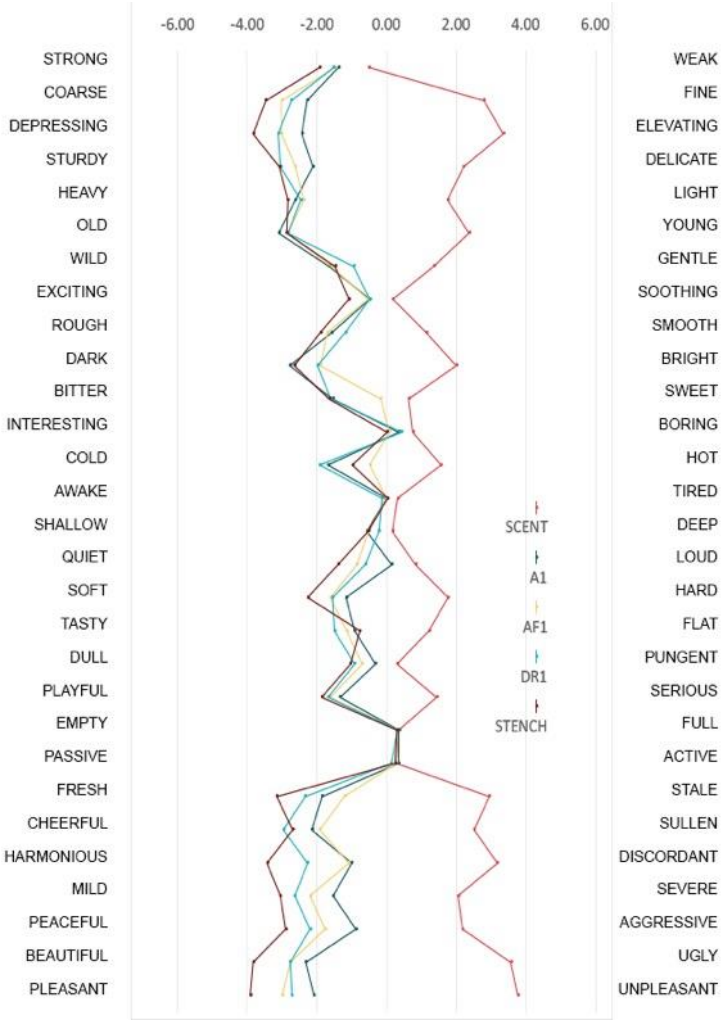


Figure 11-7. Polarity profiles from panel evaluation (total n=15). Participants were asked to rate sample 1, which consisted of a mould odour reconstruction labelled 3 ways (A1, Autumn Forest 1 and Damp Room 1). This chart shows the sum of average responses for each label, weighted, with scent and stench profiles included for reference.

In contrast, Sample 2 was positively correlated with the reference scent profile (0.74) and negatively correlated with the reference stench profile (n=-0.61). Labels showed some differences but maintained the overall trend; label A2 had a positive correlation with scent, although lower (n=0.70) than the average of all three labels. This label's correlation to the reference stench profile was also lower than average, with n=-0.55. Autumn Forest 2 had the strongest correlation with scent (n=0.77) and an average one with stench (n=0.62) for this odour. Damp Room 2 was positively correlated with scent (n=0.69) and negatively with stench (n=-0.60). According to these results, sample 2 can be characterised as hedonically pleasant.

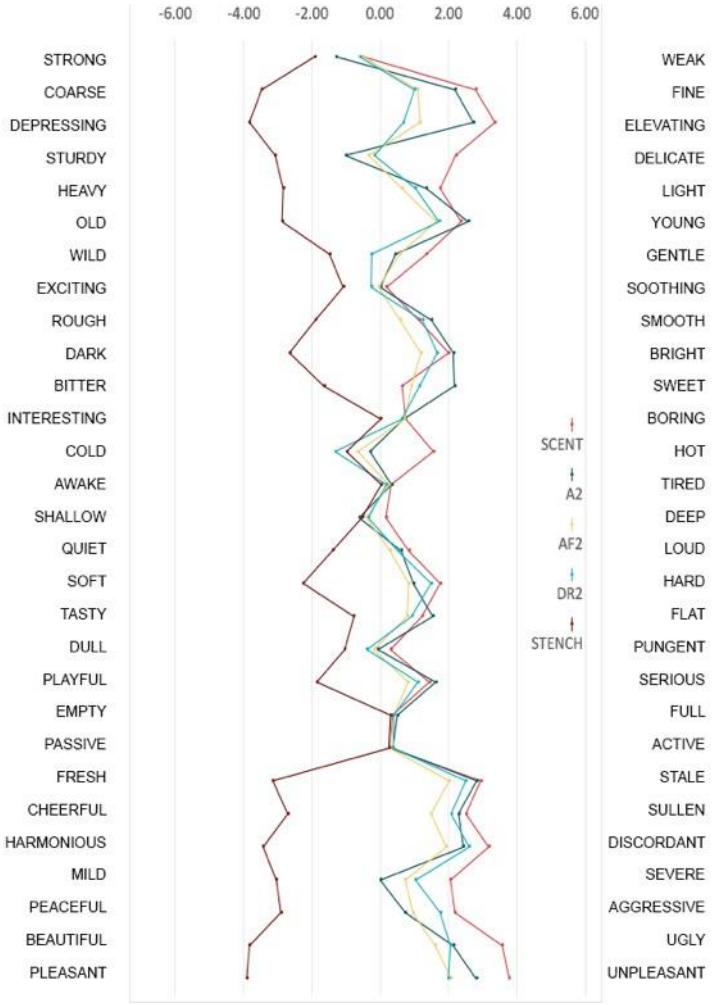


Figure 11-8. Polarity profiles from panel evaluation (total n=15). Participants were asked to rate sample 2, which consisted of a mould odour reconstruction labelled 3 ways (A2, Autumn Forest 2 and Damp Room 2). This chart shows the sum of average responses for each label, weighted, with scent and stench profiles included for reference.

Finally, Sample 3, like Sample 1, was closer to stench (n=0.76) than to scent (n=-0.70) when compared to reference profiles. In terms of each label for this odour, A3 had the strongest correlation with stench (n=0.76, compared with n=0.64 for Autumn Forest 3 and n=0.66 for Damp Room 3) and an average negative correlation with scent (n=-0.70, compared with n=-62 for Autumn Forest 3 and n=-0.56 for Damp Room 3). Sample 3 can then be characterised as hedonically unpleasant.

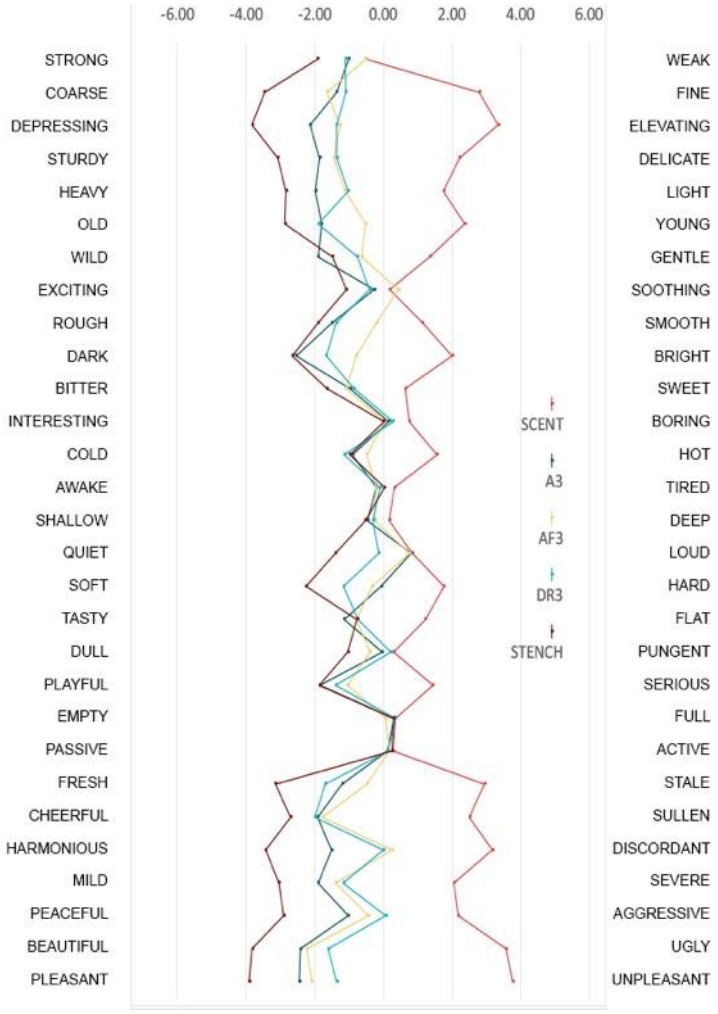


Figure 11-9. Polarity profiles from panel evaluation (total n=15). Participants were asked to rate sample 3, which consisted of a mould odour reconstruction labelled 3 ways (A3, Autumn Forest 3 and Damp Room 3). This chart shows the sum of average responses for each label, weighted, with scent and stench profiles included for reference.

In order to get an overview of the role of semantic information in the perception and report of hedonic tone for mould reconstructions, the correlations between different odours and labels were obtained following the Pearson method. Another comparison, this time of how the odours were evaluated, independently of labels, shows that there are positive correlations between all three characterisations for each odour, with different degrees of strength, as can be seen in Fig 12-10. Correlations among evaluations of all labels (A, Autumn Forest, Damp Room) within a specific sample set (1,2,3) are strong. The labels of sample 2 are the most highly correlated (A2-Autumn Forest 2: r=0.91; A2-Damp Room 2: r=0.82; Damp Room 2- Autumn Forest 2: r=0.93), followed by the labels of sample 1 (A1-Autumn Forest 1: r=0.83; A1-Damp Room 1: r=0.87;

Damp Room 1- Autumn Forest 1: r=0.86) and finally the labels of sample 3 (A3-Autumn Forest 3: r=0.77; A3-Damp Room 3: r=0.75; Damp Room 3- Autumn Forest 3: r=0.66).

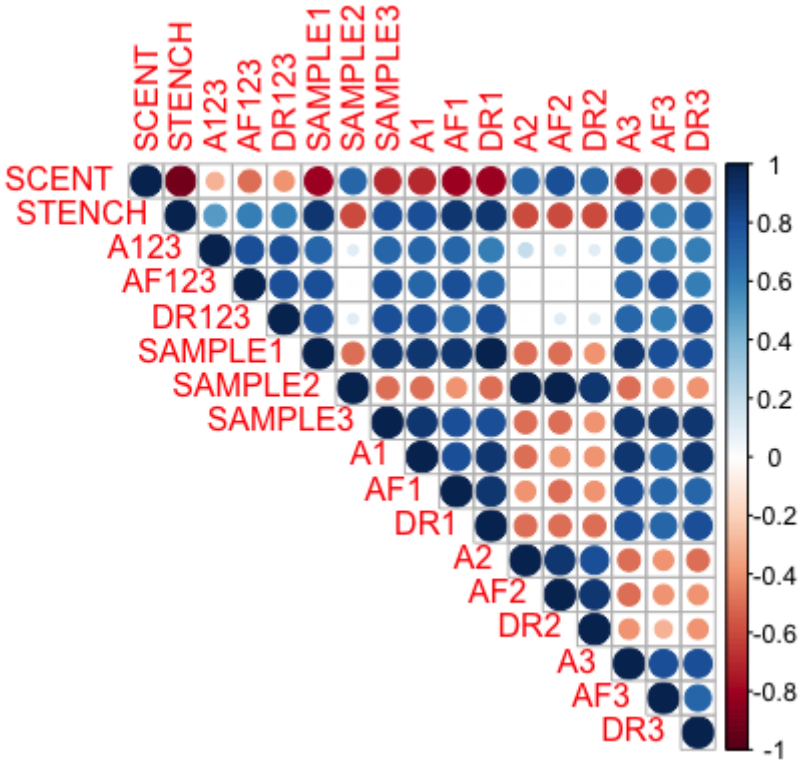


Figure 11-10. Correlations between weighted means of participants' odour evaluation results and reference values for scent and stench. The bigger and darker the circle, the stronger the correlation. Blue denotes a positive correlation and red, a negative one. Key: A123=all evaluations under label 'A'; AF123 =all evaluations under label 'AUTUMN FOREST'; DR123=all evaluations under label 'DAMP ROOM'; 'SAMPLE 1' =average of evaluations A1, AF1, DR1; 'SAMPLE 2' =average of evaluations A2, AF2, DR2; 'SAMPLE 3' =average of evaluations A3, AF3, DR3; A1=evaluations of sample 1 of odour 'A'; AF1=evaluations of sample 1 of odour 'AUTUMN FOREST'; DR1=evaluations of sample 1 of odour 'DAMP ROOM'; A2=evaluations of sample 2 of odour 'A'; AF2=evaluations of sample 2 of odour 'AUTUMN FOREST'; DR2=evaluations of sample 2 of odour 'DAMP ROOM'; A3=evaluations of sample 3 of odour 'A'; AF3=evaluations of sample 3 of odour 'AUTUMN FOREST'; DR3=evaluations of sample 3 of odour 'DAMP ROOM'.

Four key aspects from the research findings merit discussion:

The ambiguity of the smell did lend itself to differences in evaluation when character, safety, familiarity and hedonic tone are taken into account.

In terms of odour character, hedonically different labels did not affect the choice of main descriptor for the smells when semantic input was considered as the main factor in analysis, but did have impact on nuances of the characterisation, where the choice seemed to be affected by the given name.

For the same smell labelled differently, the main descriptors selected were fairly consistent across labels, but the weight of those descriptors in the overall sample characterisation varied. A slight preference of descriptors that appear semantically connected with the label was observed (e.g. 'mushroom' for Autumn Forest and 'damp' for Damp Room).

Safety was one aspect where a connection was seen between the label tone and evaluation. The main factor influencing evaluation was sensory perception (where samples evaluated more pleasant also considered safer) but a negative label (e.g. Damp Room) had a negative impact in the safety evaluation in comparison to a positive label (e.g. Autumn Forest). When the sample was evaluated as overall unpleasant, the safest smell was attributed to the positive label, then the neutral label, with the negative label being considered the least safe. When odour valence was positive, differences were less pronounced.

With regards to familiarity, the smells with positive and negative labels were deemed more familiar than then neutrally-labelled ones. Pleasant smells were rated as more familiar than unpleasant ones.

Hedonic tone evaluation results were, as expected, where slight differences could be seen in the rating on a given odour according to the way it was named, broadly supporting the findings of other studies (Herz and Clef, 2001; Rachel S. Herz, 2003). Positive names gave a more positive evaluation, and vice versa. The results are consistent across both techniques used in this study (Likert-scale rating and polarity profiles).

These findings might help us to understand the duality that the smell of mould presents and how expectations and non-sensory information can interact with sensory perception. Given that the smell has historically (and negatively) been

associated with old buildings and conservation practice, but also with the scent of nature and parks in the autumn, there are many opportunities to enrich the narrative in terms of visitor experience to historic houses, and widen the characterisation of this odour to include the more positive associations, while educating visitors in the complexities of smell perception.

One potential approach would be to think about historic smells as a process, or result of a process, of material change. Bringing back the three-scent layer of the Philip Johnson's Glass House reconstruction discussed in the pot-pourri chapter, the preservation of a historic smell could be approached as evidence of a process of material change, with one or more records characterising the odour at certain points, such as the smell of a new book, the smell of an old book and then the smell of a mouldy book, should this be relevant to the narrative. Another option would be to explore different associations for the smell, including the connection with nature in a way different from deterioration.

Chapter summary

- There are many smells with cultural significance that are ambiguous. One of them, the smell of mould, is important because it has been long associated with the pass of time and the way nature colonises human-made objects and spaces, becoming a symbol for decay and destruction. In addition, recognising this smell and understanding its implications are essential to many professionals working in heritage because this smell simbolises a risk to collections. As a result, most associations of this smell in a heritage context are negative, related to poor maintenance, waste and decay.

- The findings of a study presenting mould smell under positive, neutral and negative labels show that perceptions of edibility, familiarity, safety and pleasantness can be affected by non-olfactory information. In a case such as the smell of mould, this provides an opportunity for curators and practitioners working in heritage interpretation to expand the narrative beyond decay and encourage open interpretation of heritage smells in context. One way would be to understand smell as part of a process, allow for new interpretations and narratives, ones capable of working with the ambiguities. In such cases, thinking about an ambiguous historic artifact both as a record of human manipulation of the material world and as evidence of non-human engagements with matter, creates an opportunity where "decay reveals itself not (only) as erasure but as a process that can be generative of a different kind of knowledge" (Dawdy, 2018).

12 Methodology

12.1 VOC extraction and analysis

12.1.1 Historic paper and Library experiment

VOC Extraction and Analysis

The purpose for the VOC qualitative analysis carried out was to characterise the samples chemically, identifying the odorants that contributed to the smell as perceived to the human nose. The identified compounds were cross-referenced with odour databases to form the basis of odour quality descriptors as posed to sensory panels. VOC analysis was also undertaken to document the smell. The sample book (Panait Istrati: *Les Chardons du Baragan*, Bernard Gasset, Paris, 1928) came from a second-hand bookshop in London and was initially selected for its smell, judged representative of old books in an informal sniffing session in the lab, and validated by the finding of many representative aged-paper VOCs in this analysis. It was placed in a 5-L Tedlar bag (SKC, 232-05A) and left at room temperature for 2 weeks as an experimental approach to determining appropriate time for HS to concentrate (other books were tested at two weeks, returned to the Tedlar bag afterward, and tested again two weeks later). Then, a DVB/CAR/PDMS SPME fibre (50/30 µm) was introduced through the septum into the bag and exposed for 60 min (fibres were always preconditioned for 30 min at 250 °C in a flow of He before exposure).

In the library environment, the fibres were placed vertically on an even surface and exposed for 1 h and for 24 h. Two further blank fibres were taken to the environment but not exposed; all were then taken to the lab for analysis.

The fibres were analysed using a Perkin Elmer Clarus 500 Gas Chromatograph with a Clarus 560D Mass Spectrometer. The temperature gradient consisted of the following steps: at 50 °C hold for 10 min, 10 °C/min ramp to 100 °C, 5 °C/min ramp to 200 °C, 2 °C ramp to 220 °C, hold for 20 min, total run time 60 min. The carrier gas was He at 1 cm_3/min. The injector temperature was 250 °C (the fibre was removed after 10 min) in split mode.

The results were analysed using NIST 05 Mass Spectra Library V2.0 and the identified odorous compounds were later matched with smell descriptors using

established databases Flavornet and Perfume & Flavorist (Acree, T and Arn, 2004; Mosciano, 2019).

An external standard calibration mixture (MISA Group 17 Non-Halogenated Organic Mix 2000 mg/mL in methanol) was used to follow the performance of the instrument, using the same fibres with an adsorption time of 20 s and a gradient consisting of an initial temperature of 35 °C for 5 min, 10 °C/min ramp to 200 °C and then hold for 10 min. This method included a 2-min solvent delay. No quantitative calibration was attempted at the time due to the exploratory nature of this qualitative analysis.

Paper extraction

For the experiment which evaluated the book smell blindly in the museum,the chosen solvent was methanol (M3641, Sigma-Aldrich, Gillingham), which has been proven effective for extracting plant materials (Eloff, 1998). Its toxicity and flammability were considered potential drawbacks; so the samples were only used after methanol was evaporated.

547.45 mg of the paper sample were cut into small pieces and placed in a 1000-ml Duran bottle (previously heated overnight at 100 ^{o}C to clean it), fitted with a silicone septum. The bottle was heated in a fan-assisted oven (PN30, Carbolite, Hope) at 100 °C for 2 h. The degraded sample was then placed into a 10-ml plastic vial (60.9920.821, Sarstedt, Nümbrecht) with 7 ml of methanol. After stirring using a VWR Analog Vortex mixer for 35 min, the extract was decanted into another vial. 0.5 ml of the solution was transferred to a Chromacol 20-ml glass vial (20CV, Thermo Scientific, Loughborough), with a screwcap and a silicone septum. The extract was sampled using a DVB/CAR/PDMS SPME fibre (50/30 µm) and analysed with the GC-MS method detailed above, with extraction time 60 s.

For the sensory panel testing, an extraction was done using Dipropylene Glycol (DPG, Acros Organics, Geel, Belgium), which has been shown as a solvent with great affinity for aromatic hydrocarbons (Nicolae, Oprea and Fendu, 2015), it is practically odourless and has low toxicity in mammals (Dow Chemical, 2007). For

the extraction, 5.65 g of of the paper sample were cut into small pieces aged in a 1000-ml Duran bottle (previously heated overnight at 100 ^{o}C to clean it) and heated in a fan-assisted oven (PN30, Carbolite, Hope) at 150 °C for 2 h. The degraded sample was then placed into a 100-ml glass Duran bottle vial (Schott, Germany) with 40 ml of DPG. It was then sonicated at 60 ^{o}C in VWR Ultrasonic cleaner for 30 min. The extract was filtered twice into an amber-coloured vial and validated via a sniff test in the lab by a small group of volunteers who confirmed that it smelled close to the original book. Then, it was presented to participants to smell for the evaluation. No chemical analysis was undertaken of this extract because other aspect of this research were prioritised at the time. Given the positive findings detailed in the authenticity experiment, and the central role of the book extract in it, characterising and documenting this smell as a lab interpretation could be a line for future work.

12.1.2 Wax experiment

A sample of Black Bison Wax (Liberon UK, Learoyd Rd, New Romney TN28 8XU) was obtained from Knole's conservation department and stored at room temperature for one week. A sample of 0.063 g was introduced into a microchamber (M-CTE250, Markes International Limited, Llantrisant, UK), kept at room temperature and under a constant flow of dry nitrogen (65 ml/min). To collect a sample, a thermal desorption tube (Tenax/Carbograph5TD) was inserted in the output of each microchamber to collect a total volume of 1000 ml of headspace. Two replicate analyses were carried out.

Analysis was performed using gas chromatography olfactometry-time of-flight mass spectrometry (GC-O TOF-MS; Agilent 7890 GC, Agilent, USA and BenchTOF-dx model, Almsco, Germany). Identification was carried out using TargetView V3 (Almsco).

Separation and detection were performed using a 7890N gas chromatograph and time-of-flight mass spectrometer, using a semi-polar DB-624 capillary column (60 m, 250 µm, 1.4 µm) and He gas as the carrier at a flow rate of 1.6 ml/min. The oven temperature of the GC was initially held at 40 ºC for 5 min, then raised to 45 ºC at a rate of 2 ºC/min and then raised again to 230 ºC at a rate of 5 ºC/min and held at that temperature for 4 min.

The GC-MS interface was set at 230 ºC. The mass spectrometer acquired data in scan mode with an m/z interval from 28 to 330, operating at an electron impact energy of 70 eV.

12.1.3 Pot-pourri experiment

VOC Extraction and Analysis

A sample of the historic potpourri, prepared by contemporary perfumer Stephen Nelson following the published recipe from 1750 (Nelson, 2006) was obtained and stored at room temperature for one week. A sample of 0.074 g was introduced into a microchamber (M-CTE250, Markes International Limited, Llantrisant, UK), kept at room temperature and under a constant flow of dry nitrogen (65 ml/min). To collect a sample, a thermal desorption tube (Tenax/Carbograph5TD) was inserted in the output of each microchamber to collect a total volume of 500 ml of headspace. Two replicate analyses were carried out.

Analysis was performed using gas chromatography olfactometry-time of-flight mass spectrometry (GC-O TOF-MS; Agilent 7890 GC, Agilent, USA and BenchTOF-dx model, Almsco, Germany). Identification was carried out using TargetView V3 (Almsco).

Separation and detection were performed using a 7890N gas chromatograph and time-of-flight mass spectrometer, using a semi-polar DB-624 capillary column (60 m, 250 µm, 1.4 µm) and He gas as the carrier at a flow rate of 1.6 ml/min. The oven temperature of the GC was initially held at 40 ºC for 5 min, then raised to 45 ºC at a rate of 2 ºC/min and then raised again to 230 ºC at a rate of 5 ºC/min and held at that temperature for 4 min.

The GC-MS interface was set at 230 ºC. The mass spectrometer acquired data in scan mode with an m/z interval from 28 to 330, operating at an electron impact energy of 70 eV.

12.1.4 Mould experiment

VOC Extraction and Analysis

Mould headspace samples were taken from inside a room at a historic church in Cracow, Poland using both SPME fibres and Tenax tubes. In the area of sampling there was mould growing on many surfaces, including textiles, wood and other organic materials. This sampling location was selected as an ‘averaged example’ of historical places with mould presence.

Figure 12-1. Sampling of mould VOCs in a historic church using carbon-sorbent tubes connected to an electronic pump.

The odour active compounds were identified by GC-MS on two columns of different polarity and described by GC-O. SPME was carried out using DVB/CAR/PDMS SPME fibres left in the room for 24 h.

For samples using carbon sorbent tubes, two-bed sorbent cartridges were used to cover the range of target compounds in this test. The cartridges were stainless-steel tubes (length: 7.6×1.2 cm; o.d.: 0.6 cm) filled with a multisorbent bed of approximately 350 mg of Tenax/Carbograph 5TD (Markes International Limited, Llantrisant, UK). The two sorbent materials were selected on the basis of recommendation of manufacturer. Tubes were connected to Universal Air Sampling Pumps 224-PCMTX8 (SKC Ltd, Higher Shaftesbury Rd, Blandford Forum DT11 8ST); 1L, 5L, 10L and 25L of air volume were collected in duplicate.

Analysis of MVOCs extracted via SPME was carried out using a gas chromatograph (Trace 1310) coupled to a single quadrupole mass spectrometer (ISQ), both from ThermoScientific Inc. (USA). A RXi-5MS capillary column (Restek, USA) with the following parameters: 30 m, 0.25-mm ID, 0.25 µm of film thickness, was used for separation. The carrier gas was He and its flow during the analysis was kept at 1ml/min. The following temperature program was used for analysis: 35 ^{o}C hold for 10 min, temperature ramp from 35 ^{o}C to 130 ^{o}C at 1

^{o}C/min, temperature ramp from 130 ^{o}C to 220 ^{o}C at 5 ^{o}C/min, temperature ramp from 220 ^{o}C to 260 ^{o}C at 10 ^{o}C/min, 260 ^{o}C hold for 5 min.

The parameters of the MS detector were: MS transfer line 250 ^{o}C (1 sampling)/ 260 ^{o}C (2 sampling), electron ionization (EI) with 70 eV, and mass range of 33-650 m/z was detected in total ion current mode (TIC). Reference libraries (NIST/EPA/NIH Mass Spectral Library) from NIST MS Search program version 2.0 were used to identify the MVOCs. When required, a reference compound was used as a standard to confirm the presence of particular volatile compounds.

Following thermal desorption conducted with a Unity model instrument (Markes International Limited, Llantrisant, UK), the tubes were analysed using gas chromatography olfactometry-time of-flight mass spectrometry (GC-O TOF-MS; Agilent 7890 GC, Agilent, USA and BenchTOF-dx model, Almsco, Germany). Identification was carried out using TargetView V3 (Almsco).

Separation and detection were performed using a 7890N gas chromatograph and time-of-flight mass spectrometer, using a semi-polar DB-624 capillary column (60 m, 250 µm, 1.4 µm) and He as the carrier gas at 1.6 ml/min. The GC oven temperature was initially held at 40 ºC for 5 min, then raised to 45 ºC at a rate of 2 ºC/min and then raised again to 230 ºC at a rate of 5 ºC/min and held at that temperature for 4 min.

The GC-MS interface was set at 230 ºC. The mass spectrometer acquired data in scan mode with an m/z interval from 28 to 330, operating at an electron impact energy of 70 eV.

12.1.5 Odour evaluation

Historic paper and Library experiment

<u>Old book smell evaluation at Birmingham Museum and Art Gallery</u>

The extract of historic book was presented as a smell to the public as part of the permanent exhibit ‘Birmingham: its people, its history’ (rooms 37 to 42 of the top floor of the Birmingham Museum and Art Gallery, Birmingham, UK). The experiment was designed to take place during school holidays (July 2015) to ensure a large and diverse number of participants and was carried out over 3

days. At the end of their visit to the exhibition, respondents encountered a table with museum volunteers, who invited them to sample 8 unidentified smells (which were ‘chocolate’, ‘coal fire’, ‘old inn’, ‘fish market’, and ‘dirty linen’, coffee and HP sauce, sourced, respectively, from Dale Air (first five smells), the local coffee shop and Sainsbury’s supermarket) and to complete a short questionnaire, including a question that prompted them to describe the smell of historic book. This was presented using a piece of sterile gauze (9 x 7 cm, Sterile Absorbent Gauze BP, Boots Pharmaceuticals, Nottingham NG2 3AA, UK) soaked in 5 ml of the book extract, left to evaporate for 1 h due to the potential toxicity of the solvent base, and placed in a metal canister (9 x 5.5 cm, from homesale_estore Xin Zou, Qi Fu Road Baiyun District No.5, Guangzhou, CN, Guangdong, 510405, China) with a metal mesh as a lid. The container was closed, and the lid secured to the canister with a small metal screw (not included in the original container) to prevent the visitors from opening it. When the container was closed, the book aroma was detectable by the human nose from around a 7-10 cm distance from top of the canister. The container was labelled with a letter and no indication was given, verbally or visually, about the nature of the smell.

Historic Library smell evaluation at Wren Library at St. Paul’s Cathedral

A panel of seven untrained assessors were briefed to abstain from the use of scented products and from eating 30 min prior to the experiment, and to reveal any circumstances that might affect their sense of smell, such as a cold. The protocol also advised rating the perceived strength of the library smell as soon as assessors entered the space, to prevent olfactory adaptation (a decrease in sensitivity after a period of exposure). On the day, the group was asked to enter the space and fill in a brief form with 21 pre-given descriptors of odour quality (referenced from the findings of the chemical analysis of the environment and odour-compound databases, list available in Appendix III) plus a category of ‘other’ that they could complete. Although the effect of verbal cues on odour classification (R S Herz, 2003) was considered in the design of the experiment, the need for the panellists to use easily understood odour descriptors (as opposed to personal associations), in which they had no training, was prioritized. As part of the evaluation, the assessors were asked to also rate odour intensity

and hedonic tone against the scales outlined by German Standard VDI 3882 (Beuth Verlag, 1997).

12.1.6 Wax experiment

GC-Olfactometry

GC-sniffing analysis was performed using an olfactory detector port OP275 (GL Sciences Inc., Japan). The odour-active VOCs were measured by additional runs using the human nose of trained assessors as detector (GC-Sniffing). The chromatographic column was removed from the input of MS transfer line and connected to a shorter capillary column covered by a transfer line at 230 ºC. Panellists performed sensory evaluation of the VOCs separated by chromatography.

As soon as an assessor detected an odour, its attribute, appearance time and intensity values (from 1=very faint odour to 5=very strong odour) were assigned.

The smelling task was performed by 2 panellists, at room temperature and isolated of distractions (Acree, 2008). During the analysis, they took turns, each performing the GC-sniffing task for 15 min. Each panellist analysed a sample twice, so to cover the entire chromatogram. Only odours detected at least twice were considered, and descriptors were combined for each smell. Odour intensity values were, as routine practice, averaged for each odour (Brattoli *et al.*, 2013).

Chemical identification in GC-O

A protocol was followed to link odours perceived during the GC-O analysis with chemical compounds found in the sample. It included the following steps (summarised in the graphic below):

Phase 1

The Kovats index (KI) is used for the characterization of organic substances in gas chromatography, converting retention times into system-independent constants. In this identification, the KI of a compound present in the analysis was

calculated using a published formula (Kovats, 1958) and compared with the KI associated with the candidate compound in published and internal databases (e.g. Mayol and Acree, 2009).

The odour quality description obtained during analysis was compared with published odour descriptors for the candidate compound (Nijssen, L.M.; Ingen-Visscher, C.A. van; Donders, 1963-2018; Acree, T and Arn, 2004; Mosciano, 2019).

Mass spectra for the compound present in the analysis was compared with published mass spectra for the candidate compound following widely-used guidelines (Mayol and Acree, 2009).

If the found compound matched the candidate compound in these three steps, identification was considered achieved. If not:

Phase 2

The retention time (RT) and odour quality description for the found compound were compared with retention time and descriptors present in an internal reference database compiled by company Odournet (unpublished) with odour descriptors, retention indexes and odour threshold of compounds analysed in 20+ years.

If the found compound matched a compound present in the internal database, identification was considered achieved. If not:

Phase 3

The target ions of the found compound were compared matching query spectra to spectra present in a reference library (Koo, Kim and Zhang, 2013). If main target ions matched, identification was considered achieved. Otherwise, the compound was considered unidentified.

Some limitations of this technique that should be considered are:

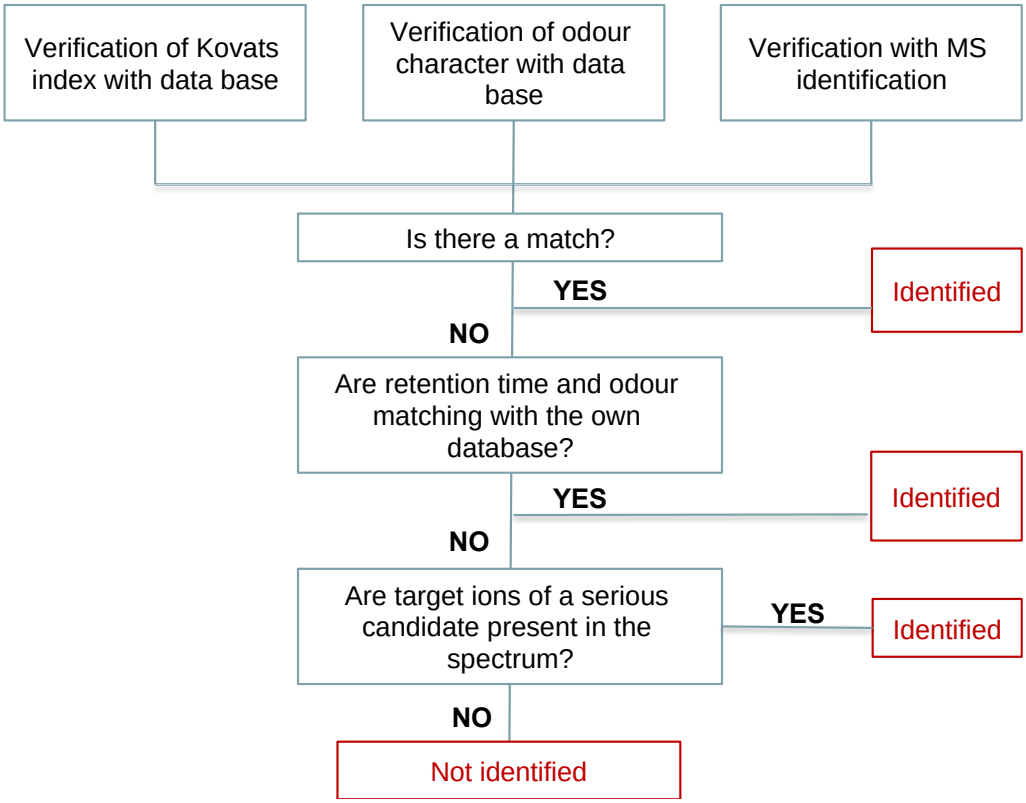
Success of analysis depends largely on the skill of the sniffers,

Because of human nose can be more sensitive than the chemical detector, some odorants can be not represented in the spectrum,

A significant percentage of odours (around 30%) can remain without chemical

identification,

Some perceived odours can be the mixture of co-eluted odour compounds. Chemical identification may not be possible.



Odour evaluation panel

Odour character

A panel of 16 evaluators were asked to refrain from eating or drinking (other than water) 30 min prior to the experiment, and to avoid the use of scented products on the day of the evaluation. Evaluators were trained by performing a sensory test of qualification on three non-consecutive days, consisting on determining at least 10 individual threshold estimates (ITE), and a maximum of 20 ITE, of the reference gas *n*-butanol in nitrogen (Asociación Española de Normalización (AENOR), 2004)). This experiment took place at Odournet facilities in Barcelona, Spain.

The evaluators were asked to evaluate the smell against pre-given descriptors of odour quality (referenced from the findings of the chemical analysis of the environment and odour-compound databases, list available in Appendix III) plus a category of 'other' that they could complete. The use of pre-given descriptors for olfactory evaluation is a frequent practice in this type of studies for industry and scientific research (Murray, Delahunty and Baxter, 2001; Rachel S. Herz, 2003).

Odour hedonic tone

A sensory evaluation panel of 16 assessors rated the odour using polarity profiles. The polarity profile is a quality scale comprising pairs of adjectives having opposite meanings. The task of the test subject is to put given terms (e.g. stench) or stimuli (e.g. odorants) in a category scale between the two extremes of meaning. Polarity profiles of emotional experiences give a very uniform result in tests carried out with different persons (Deutsches Institut fur Normung E.V. (DIN), 2010). In anticipation of the evaluation of hedonic tone using polarity profiles, the panellists were asked to complete two profiles, corresponding to their association with the idea of stench and scent, as described in EU olfactometry standards (Verein Deutscher Ingenieure, 1992). This evaluation is purely on semantic association, with no odorant present (AmtsBl. M-V, 2011). Participants were presented with the smell in a bottle labelled '1', which they sampled by removing the lid for 3 s and placing the tip of the vial 2 cm from their nostrils. They were then asked to complete the evaluation form. These consist of 29 pairs of opposing adjectives ('weak'/'strong') with a 7-point scale in between. Assessors rate their perception of the smell according to this list, and the semantic differential is calculated and correlated with reference values for 'smell' and 'stench' obtained with the same technique. For the purpose of this experiment, own values for 'smell' and 'stench' were also calibrated with the panel. In the reference values, a negative correlation of -0.86 can be measured between the two variables, in the case of the panel of evaluators used for this experiment, a negative correlation of -0.74 was measured. According to the standard, for an odour to qualify as hedonically definitely pleasant, the correlation between the

profile of the odour and the representative fragrance and stench profiles has to be greater than 0.5 and less than -0.5, respectively (the normative focuses on facility odours). The polarity profiles from the first (non-odorous) and second sessions were analysed and compared against the reference profiles for ‘stench’ and ‘scent’ included in the normative (a sample evaluation form available for reference in in Appendix III) and a visual representation of the results were used for interpretation following European guidelines (Deutsches Institut fur Normung E.V. (DIN), 2010).

12.1.7 Pot-pourri experiment

GC-Olfactometry

The methodology was described above, please refer to the previous GC-Olfactometry section for details.

Odour evaluation panel

In addition to GC characterisation, sensory evaluation was also conducted in the historic house following the European standard VDI 3882 (Beuth Verlag, 1997) for evaluation of odour intensity and hedonic tone. A panel of 9 untrained assessors were briefed to avoid using scented products on the day, avoid eating 30 min before the experiment, and to reveal any circumstances that might affect their sense of smell. The protocol also advised rating the perceived strength of the potpourri smell soon after commencing, to prevent olfactory adaptation (a decrease in sensitivity after a period of exposure). On the day, individual samples of the potpourri were decanted into clean ceramic bowls. The assessors were advised to sample the smell from a distance of 5 to 10 cm and fill in a form with 23 pre-given descriptors of odour quality (referenced from the findings of the chemical analysis and odour-compound databases, list available in Appendix III). Since descriptors were given, the effect of verbal cues on odour classification (R S Herz, 2003) was considered in the design of the experiment, but the need for the panellists to use easily understood odour descriptors (as opposed to personal associations), in which they had no training, was prioritized. The sample was also visible to assessors, so the potential influence of a related visual cue on odour

classification (Gottfried and Dolan, 2003) was also considered. As part of the evaluation, the assessors were asked to also rate odour intensity and hedonic tone against standardised scales.

12.1.8 Mould experiment

GC-Olfactometry

The methodology was described above, please refer to the previous GC-Olfactometry section for details.

Odour evaluation panel

Odour character

In addition, a panel of 15 evaluators were asked to refrain from eating or drinking (other than water) 30 mins prior to the experiment, and to avoid the use of scented products on the day of the evaluation. Once recruited, potential candidates underwent an assessment of accessibility, motivation, health condition, psychological predisposition to carry out sensory assessments and those selected were trained in general principles and assessment methods, distinguishing basic odours, completing simple sample e tests standard in odour testing such as description or intensity evaluation of n-butanol in compliance with European guidelines (Polish Committee for Standardization, 2007). This experiment took place at the Department of Microbiology of the Faculty of Commodity Science and Product in Management Cracow University of Economics in Cracow, Poland. The assessors were advised to sample the smells (presented in sniffing pens) from a distance of 5 to 10 cm and fill in a form with pre-given descriptors of odour quality (referenced from the findings of the chemical analysis and odour-compound databases, list available in Appendix III. 5). In addition, panellists rated the odours against familiarity, edibility and safety Likert-style scales, frequently used in sensory evaluation (Rachel S. Herz, 2003).

Odour hedonic tone

The panel was then asked to evaluate hedonic tone using polarity profiles using the protocol described in section Odour hedonic tone. Participants were then presented with nine samples in total (three odorous samples, each with three different labels); see odour reconstruction section for details of preparation. Samples were presented in a different order to avoid verbal priming effect (Herz and Von Clef, 2001). They were labelled as follows:

SAMPLE	LABEL
1	A1
1	AUTUMN FOREST 1
1	DAMP ROOM 1
2	A2
2	AUTUMN FOREST 2
2	DAMP ROOM 2
3	A3
3	AUTUMN FOREST 3
3	DAMP ROOM 3

The participants were asked to sample the odour by removing the lid of the sniifing pen 3 s and placing the tip 2 cm from their nostrils. They were then asked to complete the evaluation form (refer to Appendix II for an example of this form).

12.1.9 Odour representation

Odour character treemaps

- For the wax, pot-pourri and mould experiments, odour quality descriptors obtained from the GC-O were referenced with published descriptors (Nijssen, L.M.; Ingen-Visscher, C.A. van; Donders, 1963-2018; Luebke, 1995; Acree, T and Arn, 2004; Mosciano, 2019) and presented to the panel for sensory evaluation.
- The results are displayed in a treemap, a chart which displays hierarchical data in rectangles proportionally sized according to the amount of data in each category, created using Microsoft Excel 16.22. The software randomly assigns a colour to each rectangle; colours were manually adjusted to reflect the same descriptor every time throughout the thesis, to allow for comparison of findings.

Odour Wheel

Sensory descriptors obtained by GC-sniffing and panel evaluation were collected and classified according to established aroma families taken from two published odour wheels, as follows: ‘fragrant/vegetable/fruity/flowery’, ‘medicinal/phenolic’, earthy/musty/mouldy’ and ‘grassy/woody’ characteristics were modelled after Suffet and Rosenfeld’s (I. H. Suffet and Rosenfeld, 2007) ‘citrus’, ‘pungent’ and ‘spicy’ after Ann C. Noble’s (Noble *et al.*, 1987). Two further categories were created in order to represent those odours detected in analysis that did not belong to any of the previous categories, following the concept of odour wheel evolution (I. H. Suffet and Rosenfeld, 2007). These were ‘leather’ and ‘oily’. Descriptors produced with GC-O were combined with published descriptors (Nijssen, L.M.; Ingen-Visscher, C.A. van; Donders, 1963-2018; Luebke, 1995; Acree, T and Arn, 2004; Czerny *et al.*, 2011; Mosciano, 2019) to validate and contextualize the findings.

12.1.10 Surveys and questionnaires

Sample identification survey

In order to establish significance of potential case studies identified on first visits to the house and in-depth interviews with curators and conservators working in the property, a survey was circulated among the conservation team to highlight those smells that were relevant either for their connection with the history of the house, association with a conservation practice (e.g., perfumed wood treatments) or had meaning to workers or visitors to the house. This is an information-oriented case-study selection, a well-establish method (Flyvbjerg, 2011). The survey requested details on the source of the odour, a quality description of the smell and the season and frequency it had been experienced. An example is included in Appendix II.

Value questionnaire

The aim of the experiment was to gain insight into how the presence of smells in a historic house is perceived by visitors. The experiment took place at the showrooms of Knole House, over four days in the summer of 2018.

On day 1, visitors to the property encountered a bowl of Lady Betty's pot-pourri (available as prepared by perfumer Stephen Nelson) in the windowsill where it currently resides. The additions for this experiment were a card placed next to the potpourri bowl with the following text: ***Lady Betty's pot-pourri.*** *Pot-pourri is a mixture of petals, spices and salts designed to scent the home. This pot-pourri was created in 1750 by Lady Betty Germaine, a courtier of Queen Anne who lived at Knole. Perfumer Stephen Nelson prepared the current mix following Lady Betty's recipe. Vita Sackville-West, who lived at Knole, wrote about the potpourri: 'bowls of lavender and dried rose-leaves stand on the window-sills; and if you stir them up you get the quintessence of the smell, a sort of dusty fragrance, sweeter in the under layers where it has held the damp of the spices' (Sackville-West, 1923).*

The bowl containing the pot-pourri is fragile. Please be careful.

A total of 32 respondents filled the questionnaires on this day; results are reported as 'potpourri without presence'.

On day 2, the above setup was maintained, with the addition of a facilitator who stood in front of the bowl of potpourri, holding a smaller ceramic bowl with an open lid. People who stood to read the sign near the bowl on the windowsill where offered to sample the smell of potpourri from the pot. The idea behind this alternative setting was that a smaller bowl was easier to smell from, as the distance from the nose could be altered to suit the smeller. It was also supposed that the presence of a volunteer in the room (a tradition aligned what the practices throughout the showrooms at the property) might encourage members of the public to engage with the display/smell. A total of 40 respondents filled the questionnaires on this day; results are reported as 'potpourri with presence'.

On day 3, visitors to the property encountered the smell of a perfumed wax usually employed by the conservation team in the house. The wax was applied minutes prior to the opening of the showrooms in the Great Hall, going up the

staircase and in the exit staircase with no visual reference to it. A sniff test was performed before the opening to the public with about 6-8 volunteers who all reported being able to smell the wax. A total of 63 respondents filled the questionnaires on this day; results are reported as ‘wax’.

On day 4, visitors to the property did encounter a bowl of pot-pourri in the windowsill as usual, but no information plaque near it, or volunteer with a sample. A total of 57 respondents filled the questionnaires on this day; results are reported as ‘control’.

At the end of all four days, visitors were asked to fill in a short questionnaire upon exiting the showrooms. Most people were made aware of the opportunity to participate in a questionnaire by the volunteer team located at the entrance to the building. The nature of the questionnaire was disclosed as an activity to gain information about visitor’s experience of the showrooms during that day. The 9 questions of the survey were designed to understand how visitors were engaged via different sensory modalities and elicit attitudes towards the visit. A sample questionnaire is provid for reference in Appendix II.

Figure 12-2. Setup for value experiment. Clockwise: DAY 1: Potpourri display with information card as displayed. DAY 2: Container with decanted potpourri offered to visitors by facilitator. DAY 3: Great Hall benches and exit staircase where the perfumed wax was applied. Exit from the showrooms, where visitors completed the survey. DAY 4 was a control day, where the showrooms were maintained as usual.

Authenticity questionnaire

The aim of the experiment was to compare self-reports of perception of a smell of similar description (smell of old books/smell of historic library) recreated with two different approaches, one a direct extraction from the source, and one an artistic interpretation. The experiment took place in two stages: presential evaluations conducted in a neutrally decorated meeting room at UCL Central House building in Central London and a self-reports via an online survey service (Surveymonkey) after receiving the samples by post, to a total of 33 participants, working with the guideline that n=30 or over is indicated as a boundary for a non-small sample (Hogg, R.V. & Tanis, 2010). Both studies were conducted in the spring of 2019.

Figure 12-3. Setup for sensory evaluation in the authenticity study. Vial A contained a gauze smelling of the interpreted historic library and vial B a gauze with the smell of the book extract.

The samples were presented in an amber vial with a scent-soaked gauze inside. Vials were labelled “A” and “B”. A sample questionnaire is provided for reference in Appendix II.

12.1.11 Data analysis

Data obtained from odour evaluation panels and surveys was analysed using a combination of qualitative and quantitative methods.

Statistical analysis was conducted using Excel 2016 and RStudio (Version 1.1.463). Tests performed include:

- Student t-test: to determine if there is a significant difference between the means of two groups
- Hotelling test: a variation of t-test used in multivariate hypothesis testing
- Proportion test: uses for testing the null hypothesis that the proportions (probabilities of success) in several groups are the same
- Pearson's correlation coefficient: measure of the dependency between variables x and y

For the experiment testing value (Value questionnaire**)** non-respondents (under 10% of participants) were excluded. Responses to smell stimuli versus control were calculated using proportion tests (previously, positive and negative responses were combined in two groups (-1 and -2) and (1 and 2) to make conclusions more reliable due to small sample size in some of the answers (working with the guideline that n=30 or over is indicated as a boundary for a non-small sample (Hogg, R.V. & Tanis, 2010); differences and correlations between perception modalities and responses to questions about visit enjoyment were calculated using t-test and correlation coefficients respectively.

Data from the authenticity study was analysed using hierarchical analysis (for odour descriptors) and t-tests to determine statistical significance. Responses to questions related to potential source of the samples were analysed using the Dempster-Shafer theory of evidence, a framework for combining evidence and dealing with uncertainty (Orr, 2018), which has been applied to improve odour source location by robots (Ji-Gong *et al.*, 2015). The following weights were applied to each of the possible responses (please refer to the questionnaire in Appendix II for the original statements), normalised here to add up to one:

Levels		3	2	1	0	-1	-2	-3
A	Very likely	0.317	0.205	0.136	0.087	0.045	0.026	0.016
B	Likely	0.254	0.256	0.182	0.130	0.091	0.051	0.032
C	Moderately likely	0.190	0.205	0.227	0.174	0.136	0.103	0.063
D	Neutral	0.127	0.154	0.182	0.217	0.182	0.154	0.127
E	Moderately unlikely	0.063	0.103	0.136	0.174	0.227	0.205	0.190
F	Unlikely	0.032	0.051	0.091	0.130	0.182	0.256	0.254
G	Very unlikely	0.016	0.026	0.045	0.087	0.136	0.205	0.317

12.1.12 Odour reconstruction

Historic Library interpretation

The smell of historic library was created “from memory” (McCartney, 2019) by perfumer Sarah McCartney after a visit to St Paul’s Cathedral Library to personally sample the smell by sniffing (no scientific analysis was undertaken). The collaboration with McCartney did not specify the disclosure of a detailed formula; these were the compounds used in the preparation:

- Vanillin
- Black tea extract
- Tobacco absolute
- Virginian cedarwood
- Atlas cedarwood
- Oakwood extract
- Frankincense
- Cocoa Extract
- Saffraleine
- Karmawood

Smells of mould

The smells of mould were created in the lab by Prof. Tomasz Sawoszczuk and his team at Cracow University of Economics, using 6 compounds in different combinations. The compounds were decided upon as follows: firstly, the compounds identified as contributing to the smell were referenced from my own unpublished findings in collaboration with the Department of Microbiology of the Faculty of Commodity Science and Product in Management Cracow University of Economics in Cracow, Poland, which specialises in MVOC analysis using SPME. Of those, 3 (furfural, α-pinene and 3-carene) were found during preliminary HS-SPME-GC/MS and HS-TD-GC/TOFMS analyses of the mould at the church; 2 (1-octen-3-ol and 3-octanone) were found during the HS-SPME-GC/MS analysis and 1 (geosmin) was found during the HS-TD-GC/TOFMS analysis. The relevance of the compound selection was then validated with published references to mould VOCs (Lappalainen *et al.*, 2015; Narváez-Rivas *et al.*, 2016; Sawoszczuk and Syguła-Cholewińska, 2017; Bembibre, C, Sawoszczuk, T, Strlic, 2018). Then, mixtures were prepared by dissolving the measured volume of compound in 10 ml of dipropylene glycol (DPG). The volume was measured

after calculation was done with the automatic pipettes. The solution was shaken after preparing. In the next step the solutions were transferred into sniffing-pens with the automatic pipettes; 4ml of solution was pipetted into each pen. Below are the preparation notes; odour descriptors taken from databases (Luebke, 1995; Acree, T and Arn, 2004); geosmin was purchased already diluted in DPG in a 1% concentration from Pell Wall Perfumes (Shropshire, UK). The other compounds were sourced from Sygma Aldrich UK.

SAMPLE	COMPOUND	CAS	CONCENTRATION IN DPG	ODOUR DESCRIPTION
1	3-octanone	106-68-3	5.00%	fresh herbal lavender sweet mushroom
	1-octen-3-ol	3391-86-4	10.00%	mushroom earthy green oily fungal raw chicken
	geosmin	16423-19-1	1%	beet, earth
2	3-carene	13466-78-9	5.00%	sweet citrus terpenic fir needle
	furfural	98-01-1	5.00%	bread, almond, sweet
	α-pinene	7785-26-4	5.00%	pine
3	α-pinene	7785-26-4	5.00%	pine
	1-octen-3-ol	3391-86-4	5.00%	mushroom earthy green oily fungal raw chicken
	geosmin	16423-19-1	1%	beet, earth

13 Conclusions

The impact that smells can have on our perception of history, and heritage in general, make understanding and documenting sensory experiences related to cultural heritage highly relevant. The aim of the present work was to highlight the lack of systematic exploration of the role of smells in our perception of and engagement with the past, and to address the absence of a framework to investigate smells with cultural significance.

In this thesis, I demonstrated how smells are part of our cultural heritage and proposed a structured approach to researching them.

I defined a heritage smell as one resulting from a process of inventory among the population of a place, not necessarily linked to an existing geographical source, or a smell that carries cultural significance for its associations with a historical source, practice or event.

The connections of the olfactory with other aspects of cultural heritage, such as language, history and tourism, were highlighted, and I stressed the role of communities in nominating smells with cultural significance. In respect to systematic research, I offered examples of how current values to assess the significance of built heritage could be used as a base to identify heritage smells within the proposed framework.

In order to gain understanding on the nature of heritage smells, I showed how a holistic approach to VOC/odour analysis, comprising both chemical analysis and sensory evaluation, can successfully characterise smells and document them for the future, enabling reconstruction and preservation. The limitations to the chosen methodology were discussed, and further research could explore how to overcome some of them, such as the systematisation of the vocabulary to characterise historic smells and the development of expertise around their analysis using GC-O, in collaboration with the industries currently developing and

improving the expertise for this technology, such as odour-nuisance management, perfumery and flavour analysis.

I reviewed frequently-used techniques to visualise smells and proposed the odour wheel as a documentation tool, noting its methodological limitations regarding language standardisation and reductivity, but arguing its practical advantages for archiving, training and public engagement within heritage. In addition, I presented a novel application of the odour wheel, as a heritage tool, with two examples of how it could work in practice for smell description and training, and additionally for public outreach. Complementarily, I also identified aspects of smell characterisation that are left out of the wheels but are essential contributions to the significance and as such to conservation, such as personal descriptions connecting the smell with places, practices and historic times that need to be preserved. Several questions remain to be answered about the theory and practice of a historic smell archive, such as the nature and amount of metadata to preserve, not only characterising the smell but providing those smelling it in the future with adequate guidance should they seek to experience the odour as close as possible to the original perceivers; this is one of the key directions to move this research forward and widely, inviting contributions from chemists, artists, social historians, anthropologists and archivists, among others.

Whether or not a smell was perceived as authentic in a heritage setting was identified early in this research as an important line of enquiry, because it affected how olfactory information, along other sensory stimuli, was processed. This view is supported by previous findings on how perceived lack of authenticity in relation to the object or space can result in a negative predisposition towards the scenario. The preservation of historic odours and approaches to reconstructing smells that are lost were reviewed in the context of a study and the value of interpretation in heritage odour reconstruction was revealed. In addition, the importance of disclosing authorship and informing audiences about original conditions of perception and functions of historic smells were highlighted as key aspects of authenticity. This is a relevant finding for heritage and industry

practitioners using smells as part of multisensory exhibits, with practical applications such as the consideration of scientific and artists interpretations of historic smells in exhibitions and the exploration of the potential of public engagement in smell documentation, evidenced by the individual accounts for the smell significance that were collected during the study.

Non-olfactory information affects odour perception and evaluation, and expectations play an important role in hedonic tone judgement. In a historic house, a historic odour is perceived as more pleasant than in the lab. Therefore, careful consideration should be given to the presentation of historic smells as part of the narrative of a space or collection and for public engagement. A contextualised integration of smells into displays and exhibits, alerting the visitors of the historical changes in sensibility and functions of the odours, and using the opportunity to highlight connections between a historic environment and historic smells, might contribute to the perception of the odours as authentic and might influence the overall pleasantness and engagement of the experience.

The results of my study on smell reconstruction show that hedonic perceptions are the primary dimension in odour evaluation. In this respect, the findings of this investigation complement those of earlier studies. I've also shown that semantic labels can, however, have an effect into how the overall scent is perceived. In a case such as the smell of mould, this provides an opportunity for curators and practitioners working in heritage interpretation to expand the narrative beyond decay and encourage open interpretation of heritage smells in context, taking advantage of existing resources such as gardens and grounds.

In terms of value, the opportunity to engage visitors through multisensory exhibits has been demonstrated in the previous chapters. The results of the survey in a historic house showed that audiences were least engaged by olfactory stimuli in comparison with other sensory stimuli but that there was great potential to do so, especially in the context of the prevalent visual conditioning for engaging with the environment. These results, coupled with the evidence of the power of smells to

connect us with the past, strongly support the case for further research into how this potential might be realised. This is one of the key findings of this project and opportunities for future work, due to its capacity to transform the way narratives and engagement with a multisensory component are developed in the heritage field.

As I have shown in these conclusions, the findings of this work have a number of practical implications and opportunities for researchers and practitioners in heritage, perfumery, chemistry, linguistics, anthropology and history. Some of them are:

1. The need for a body of systematic research into smells with cultural significance to be built, as a first step to creating policies with the objective of protecting olfactory heritage.
2. The development of heritage-specific odour descriptors and training that can enable high-quality research via chemical and sensory analysis, encouraging knowledge transfer from academia to industry and vice versa.
3. The creation of a training programme in the importance and specificities of working with scents for heritage practitioners. In conservation, this could translate into facilitating the development of considerations about practices such as object cleaning, documenting and preserving odours. Also, the importance of taking significance into account when evaluating the effect of VOCs on materials, objects and collections. For curators, the focus could be exploring notions of authorship, authenticity and contextualising smells in heritage settings.
4. The collaboration with heritage stakeholders and the wider community to identify and nominate smells with cultural significance, supporting the development of related awareness about ways to enjoy, describe, visualise and communicate smells.
5. The discussion of this research in the fields of smell disorders and synaesthesia, two areas rapidly developing odour-related knowledge. My research is potentially of interest because (a) it aims to document smells beyond the ephemeral sensation, and therefore put a sensory experience

into a context accessible to hyposmics and anosmics and b) the exploration of olfactory stimuli in connection with other metadata is of relevance to synesthetic research. In turn, a productive knowledge exchange could take place.

In the opening line of these conclusions, I stated that this research is justified and made relevant by the way smells impact our perception of heritage, and also the way heritage and history can have an impact on the way we perceive smells. We know very little about the smells of the past, in part because there has not been a systematic effort to document and preserve those scents. Once a smell is lost, the practices, skills, memories of people and places, local identities are also potentially gone. A key policy priority should be to build on the precedent of UNESCO's recognition of Grasse's nomination and develop a roadmap towards protecting our olfactory heritage.

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15 List of images

16 Appendices

16.1 APPENDIX I

16.1.1 Example chromatograms

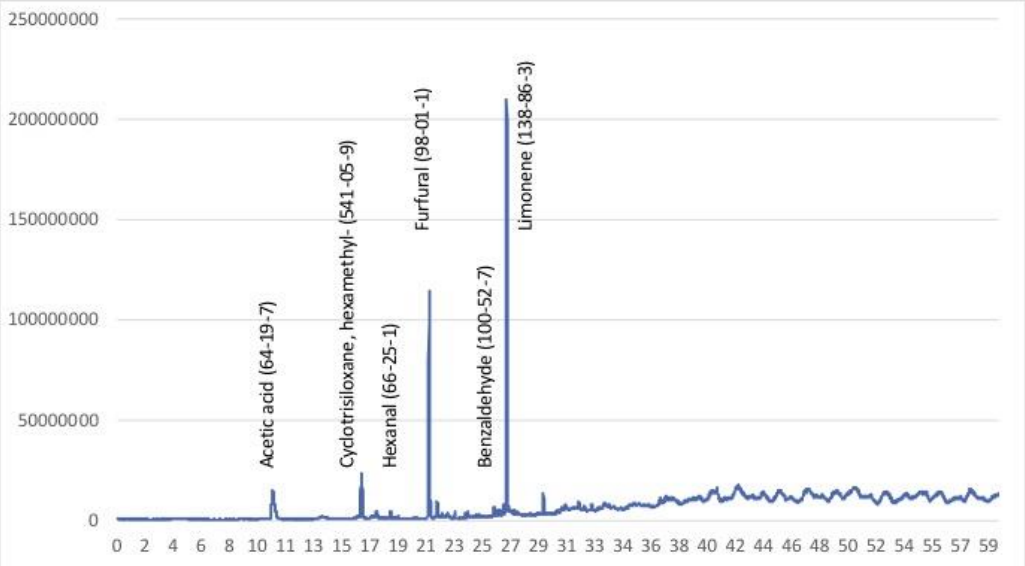


Figure 16-1. Chromatogram showing HS-SPME-GC-MS analysis of St Paul's Cathedral Library. X axis indicates time (min), Y axis indicates relative abundance. A selection of compounds identified are named for reference (for a complete list, please see Tab.9-1).

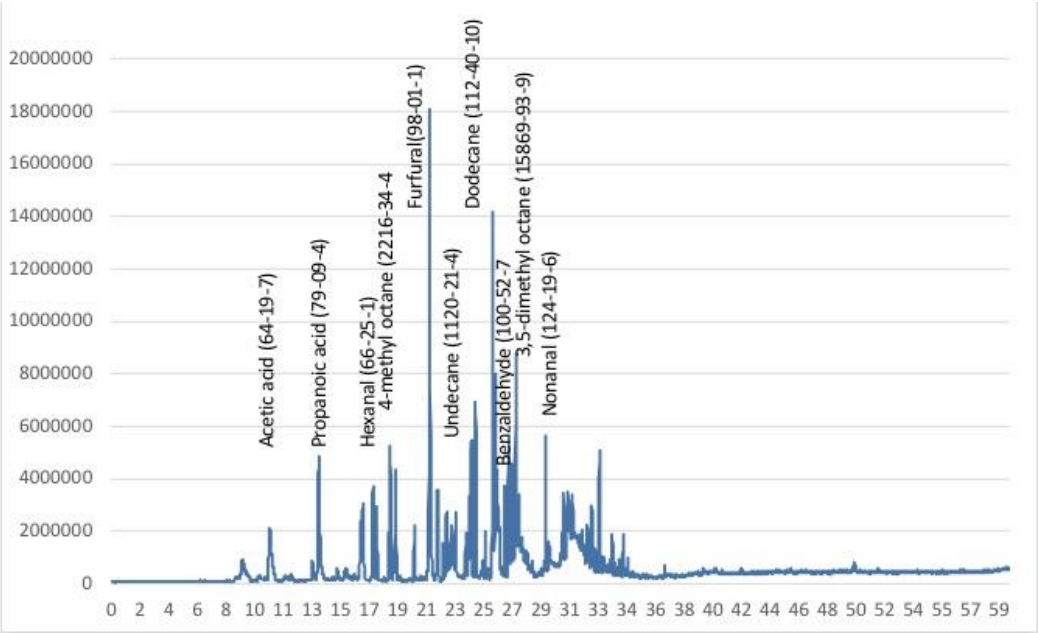


Figure 16-2. Chromatogram showing HS-SPME-GC-MS analysis of an old book (Panait Istrati: Les Chardons du Baragan, Bernard Gasset, Paris, 1928). X axis indicates time (min), Y axis

indicates relative abundance. A selection of compounds identified are named for reference (for a complete list, please see Tab.9-1).

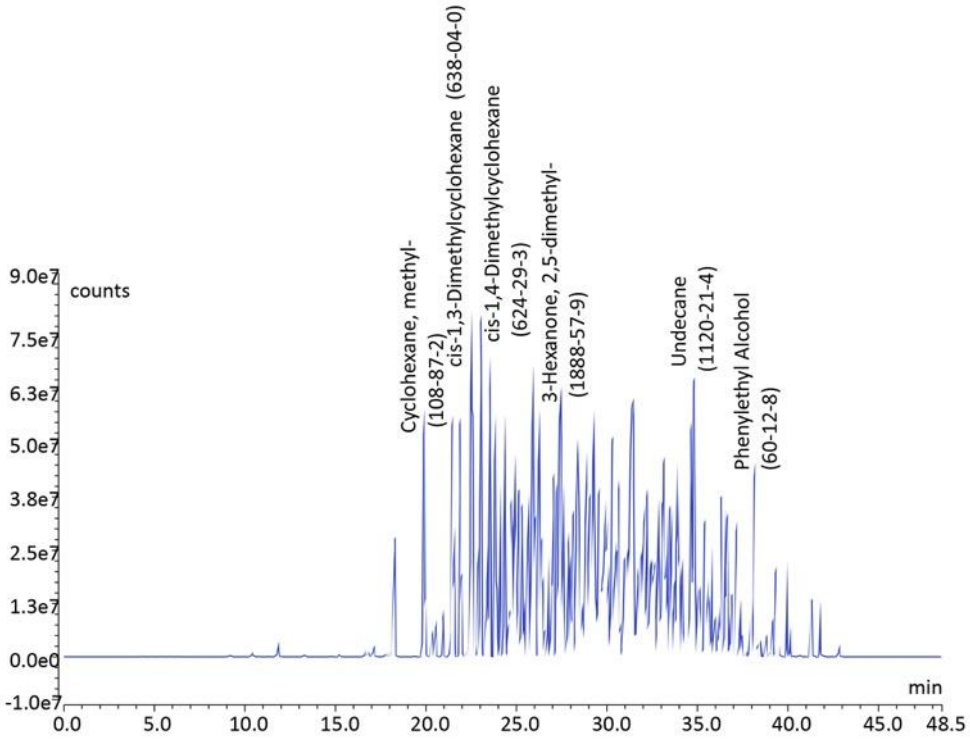


Figure 16-3. Chromatogram showing HS-TD-GC-ToF-MS analysis of Black Bison wax. X axis indicates time (min), Y axis indicates relative abundance. A selection of compounds identified are named for reference (for a complete list, please see Tab.10-1).

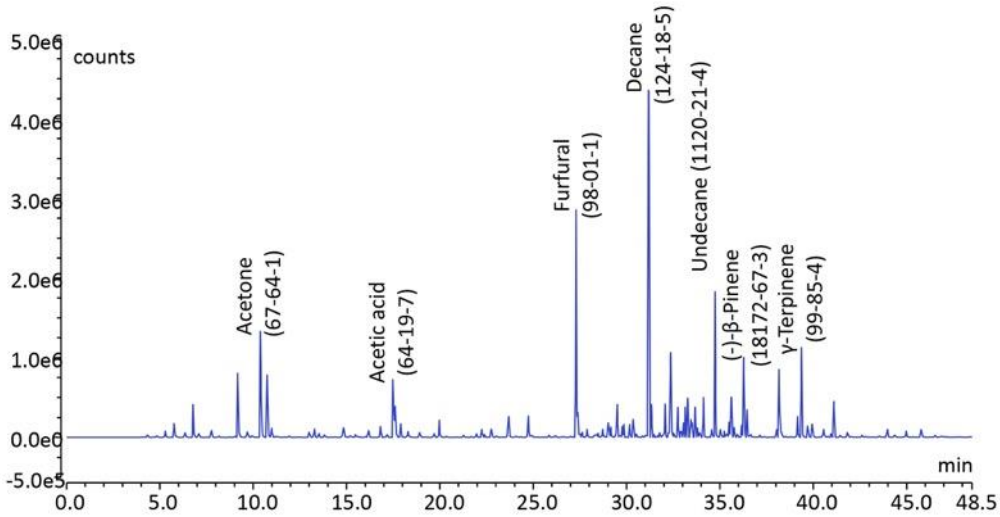


Figure 16-4. Chromatogram showing HS-TD-GC-ToF-MS analysis of Knole's historic pot-pourri. X axis indicates time (min), Y axis indicates relative abundance. A selection of compounds identified are named for reference (for a complete list, please see Tab.11-1).

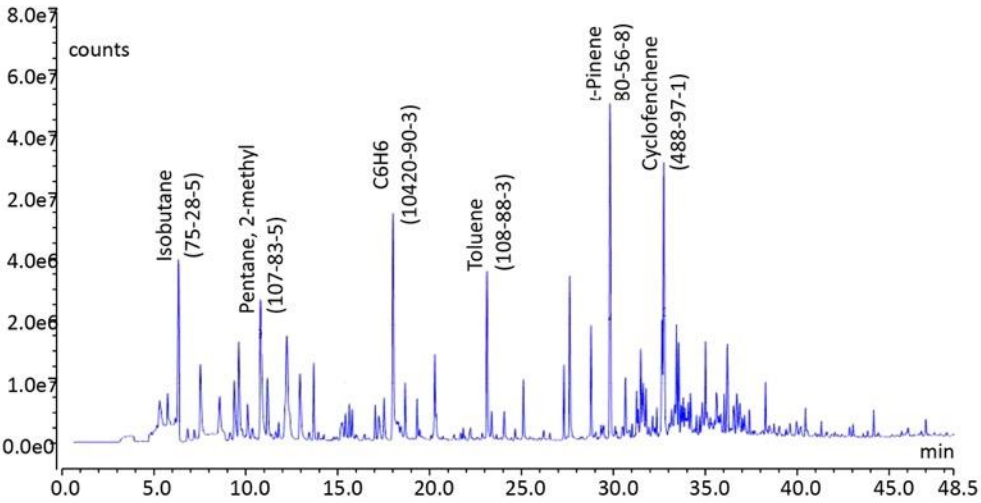


Figure 16-5.Chromatogram showing HS-TD-GC-ToF-MS analysis of mould in a historic church. X axis indicates time (min), Y axis indicates relative abundance. A selection of compounds identified are named for reference (for a complete list, please see Tab.12-1).

16.2 APPENDIX II

16.2.1 Sample identification questionnaire

Conservation Team for Dana

Smell of *Heritage*

SMELL OF HERITAGE

This project explores the connection between olfaction and heritage. We are interested in the smells in and around Knole House because we think they are an integral part of the identity of the place.

Have you noticed any smelly objects or spaces in the property (for example: wax polish, a spice cabinet)? Please write down some details!
Survey Information: There is no need for you reveal any personal details in this questionnaire. No data can or will be used in a personally identifiable manner. By returning this questionnaire you are consenting for The National Trust staff and UCL students involved in this research to use the responses in our analysis and to publicly discuss the results of this research. By completing the table below, you agree to the above.

	Source of smell (object / space)	Describe the smell in a few words	Approximate time of the year you noticed the smell	If an object or smaller space, please note location in the house
1	Harrds wax	*Tin in 'plan' cupboard, Very strong		*
2	Renaissance wax	" " "		
3	Upper King's room, attics	Dusty	Year round	
4	King's Room, behind glass		Year round, may change with project	
5	Lead stairs	moth balls	Year round	
6	Lady Betty's Rooms	popery, warm	" "	
7	Denebian Dress room	Rush matting, dry	" "	
8	Leicester gallery	Damp	Winter	Particular King James portrait end
9	Venetian bedroom	Damp, musty		
10	Ballroom	warm	Particularly on a sunny day	

KNOLE HOUSE ◆ JUNE 2018 ◆ VISITOR EXPERIENCE QUESTIONNAIRE

This is a survey to learn about your experience visiting the showrooms. Please complete all questions. Thank you!

1. What is your gender?
[ ] Male
[ ] Female
[ ] Other (please specify)_____
[ ] Prefer not to disclose

2. What is your age?
[ ] Under 18
[ ] 18-29
[ ] 30-44
[ ] 45-59
[ ] 60 +

3. How often do you visit Heritage Sites, e.g. Knole House?
[ ] Almost never
[ ] Once or twice a year
[ ] Every few months
[ ] Monthly
[ ] Weekly or more

4. Do you have any of the following?
[ ] A hearing condition that prevents you from hearing what is said in normal conversation even with a hearing aid.
[ ] An eyesight condition that prevents you from reading a newspaper even when wearing glasses or contacts.
[ ] Any condition that substantially limits your perception of smells.
[ ] Any other physical disability.
[ ] Any emotional or mental disability.

5. Most of us experience the world through sights, sounds, smells and textures. How would you rate your sensory engagement during this visit?

a. There were interesting things to see / read
[ ] Strongly Agree
[ ] Agree
[ ] Disagree
[ ] Strongly Disagree

b. There were interesting sounds
[ ] Strongly Agree
[ ] Agree
[ ] Disagree
[ ] Strongly Disagree

c. There were interesting smells
[ ] Strongly Agree
[ ] Agree
[ ] Disagree
[ ] Strongly Disagree

c. There were interesting textures
[ ] Strongly Agree
[ ] Agree
[ ] Disagree
[ ] Strongly Disagree

6. I found the visit today full of new and relevant information.
[ ] Strongly Agree
[ ] Agree
[ ] Disagree
[ ] Strongly Disagree

7. I discovered something new and exciting during the visit.
[ ] Strongly Agree
[ ] Agree
[ ] Disagree
[ ] Strongly Disagree

8. I felt a personal connection with the history / the people / the spaces of this house.
[ ] Strongly Agree
[ ] Agree
[ ] Disagree
[ ] Strongly Disagree

9. An aspect of the exhibition brought back the memory of an event/a person/an object of my past.
[ ] Strongly Agree
[ ] Agree
[ ] Disagree
[ ] Strongly Disagree

UCL www.odournet.com Smell of Heritage National Trust

16.2.3 Authenticity questionnaire

SMELL A

Please answer the questions to record your experience of SMELL A. It is all about your own impression. Be intuitive, spontaneous and quick!

1. **Describe this smell using your own words:**_____ _____ _____

2. **Is this smell…?** [ ] Edible [ ] Non-edible [ ] I'm not sure

3. **Using the scale below, please circle your first impression of the smell familiarity:**

Very familiar	Familiar	Moderately familiar	Neutral	Moderately unfamiliar	Unfamiliar	Very Unfamiliar

4. **Using the scale below, please circle your first impression of the smell safety**

Very safe	Safe	Moderately safe	Neutral	Moderately dangerous	Dangerous	Very dangerous

5. **How likely are these objects to be associated with the smell (as the source, for example):**

A piece of clothing	Very likely	Likely	Moderately likely	Neutral	Moderately unlikely	Unlikely	Very Unlikely
A cleaning product	Very likely	Likely	Moderately likely	Neutral	Moderately unlikely	Unlikely	Very Unlikely
A vehicle	Very likely	Likely	Moderately likely	Neutral	Moderately unlikely	Unlikely	Very Unlikely
A book	Very likely	Likely	Moderately likely	Neutral	Moderately unlikely	Unlikely	Very Unlikely
A cosmetic product	Very likely	Likely	Moderately likely	Neutral	Moderately unlikely	Unlikely	Very Unlikely
A building material	Very likely	Likely	Moderately likely	Neutral	Moderately unlikely	Unlikely	Very Unlikely
Rubbish	Very likely	Likely	Moderately likely	Neutral	Moderately unlikely	Unlikely	Very Unlikely

[ ] Other:_____

6. **How likely are these environments to be associated with the smell (as the source, for example)?**

A home	Very likely	Likely	Moderately likely	Neutral	Moderately unlikely	Unlikely	Very Unlikely
An office	Very likely	Likely	Moderately likely	Neutral	Moderately unlikely	Unlikely	Very Unlikely
A park	Very likely	Likely	Moderately likely	Neutral	Moderately unlikely	Unlikely	Very Unlikely
A library	Very likely	Likely	Moderately likely	Neutral	Moderately unlikely	Unlikely	Very Unlikely
A theatre	Very likely	Likely	Moderately likely	Neutral	Moderately unlikely	Unlikely	Very Unlikely
A train	Very likely	Likely	Moderately likely	Neutral	Moderately unlikely	Unlikely	Very Unlikely
A coffee shop	Very likely	Likely	Moderately likely	Neutral	Moderately unlikely	Unlikely	Very Unlikely

[ ] Other:_____

7. **Can you rate your experience of this smell? (Please circle your answer)**

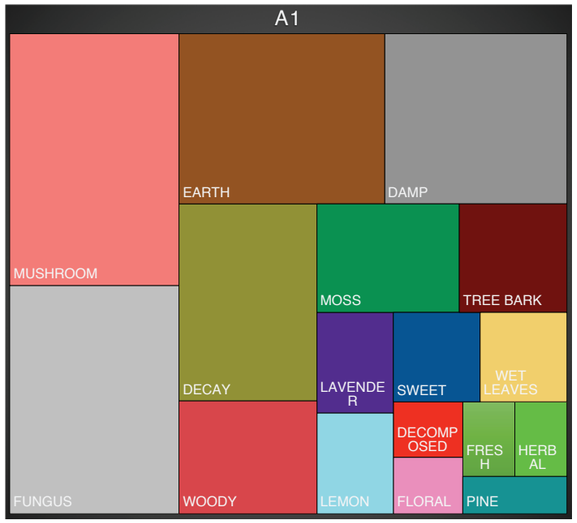
Very pleasant	Pleasant	Moderately pleasant	Neutral	Moderately unpleasant	Unpleasant	Very unpleasant

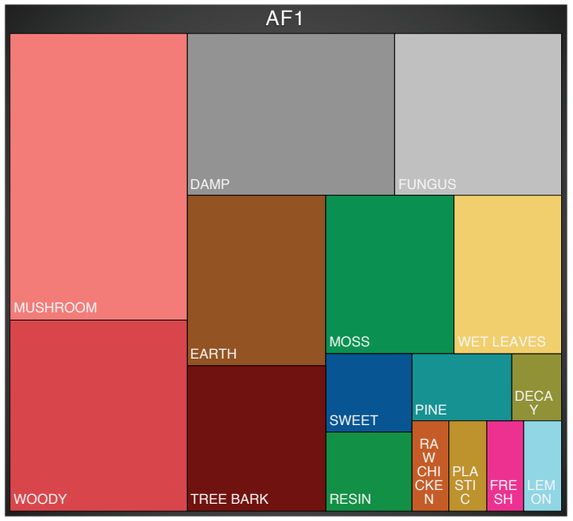
16.3 APPENDIX III

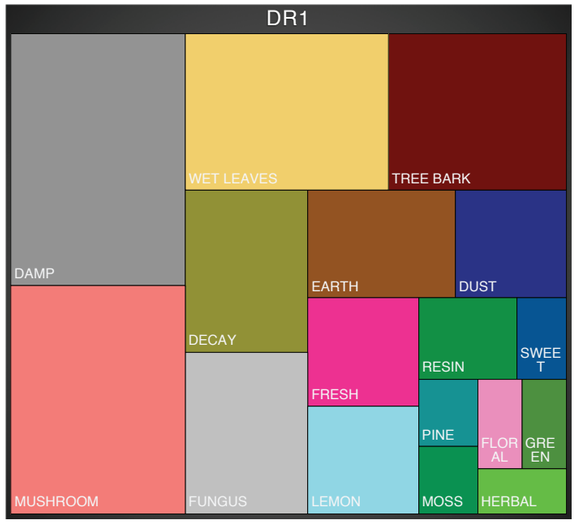
16.3.1 Book descriptors	16.3.2 Wax descriptors		16.3.3 Pot-pourri descriptors	16.3.4 Mould descriptors
Almond	Acid	Shoe polish	Broth	Acetone
Bread	Almond	Smoky	Cinnamon	Almond
Chemical	Aniseed	Solvent	Citric	Beetroot
Citrus	Balsamic	Spicy	Earthy	Bread
Creamy	Bitter	Sweet	Eucalyptus	Creamy
Earthy	Blackberry	Synthetic	Fermented	Damp
Fatty	Building site	Talcum powder	Floral	Decay
Floral	Chamomile	Wood	Fresh	Decomposed
Fruity	Cinnamon		Fried food	Dust
Green	Creamy		Gasoline	Earth
Medicinal	Damp		Green	Fermented
Minty	Dry grass		Hay	Floral
Musty	Fatty		Liquorice	Fresh
Paint	Floral		Mothballs	Fungus
Pungent	Fresh		Mushroom	Green
Rancid	Fruity		Oily	Herbal
Smoky	Green		Organic	Lavender
Sour	Honey		Other	Lemon
Sweet	Incense		Pine	Milk
Vanilla	Insecticide		Roses	Moss
Woody	Lactic		Rotten	Mothballs
	Liquorice		Rubber	Mushroom
	Mango		Sour	Oily
	Marker pen		Spices	Other
	Minty		Sweet	Pine
	Mothballs		Synthetic	Plastic
	Mouldy		Tea	Raw chicken
	Mushroom		Toasted	Resin
	Old		Vanilla	Sweet
	Paint			Toasted
	Pepper			Tree bark
	Pungent			Wet leaves
	Rose			Woody
	Rubber			
	Saliva			

16.3.5 Mould treemaps

Sample 1







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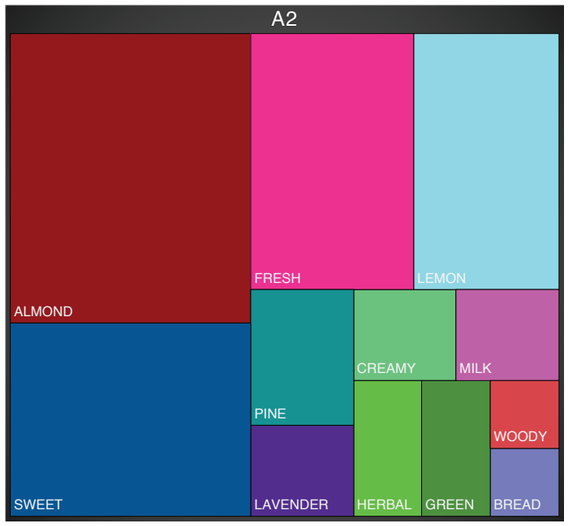
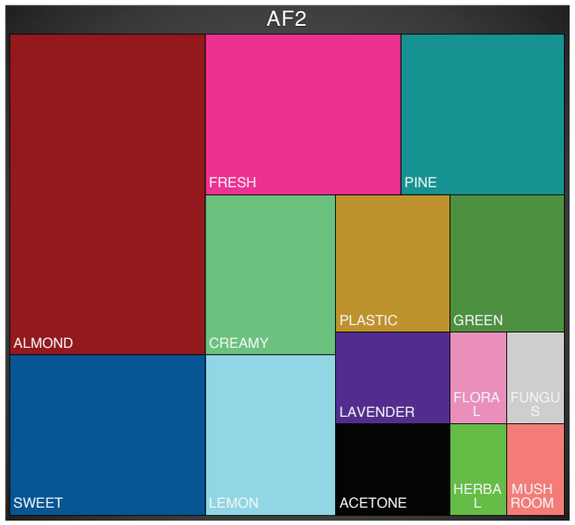
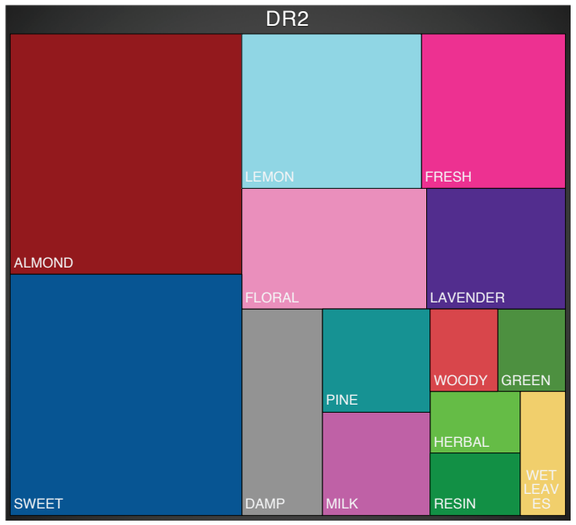
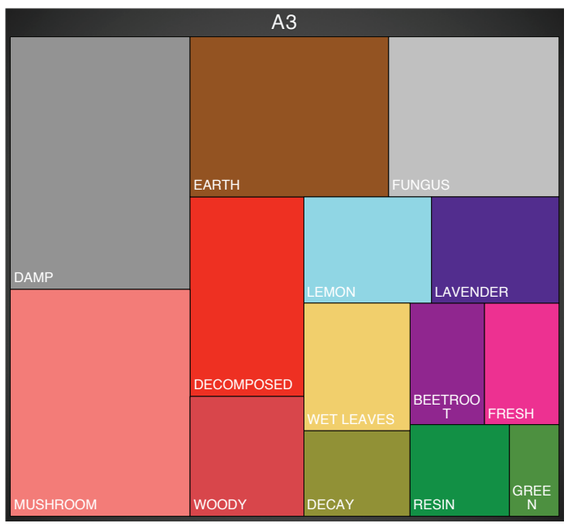
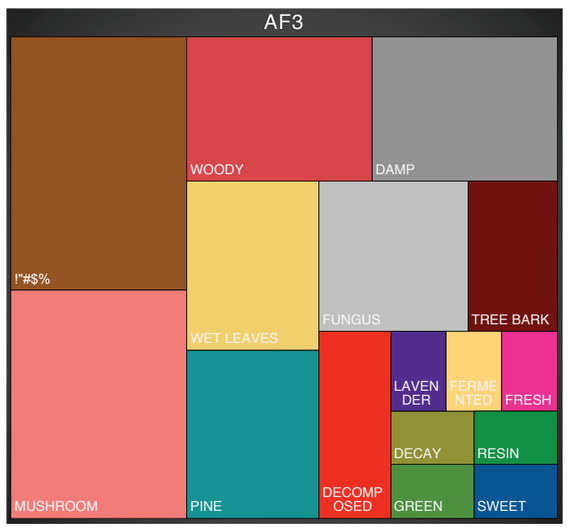


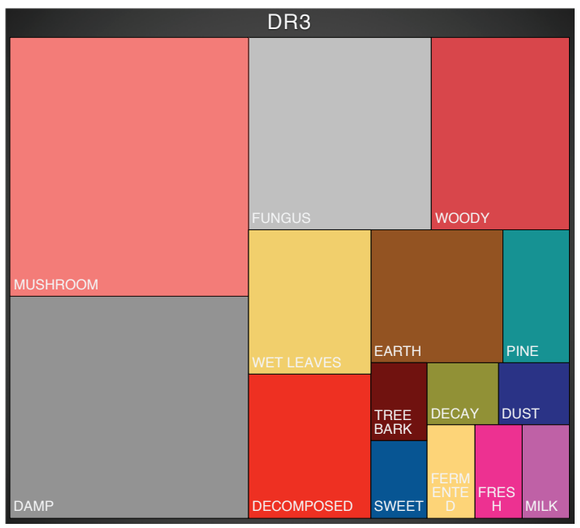




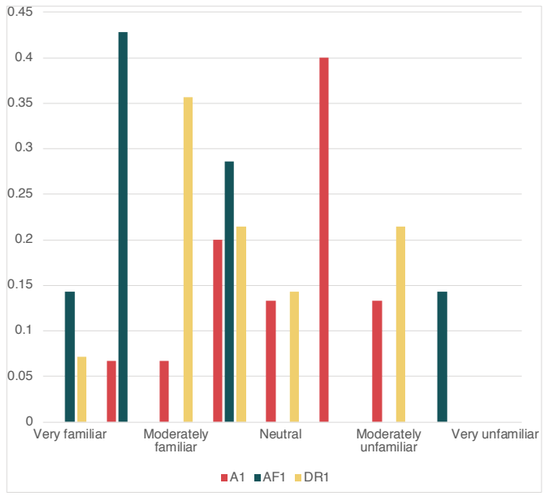
Sample 3

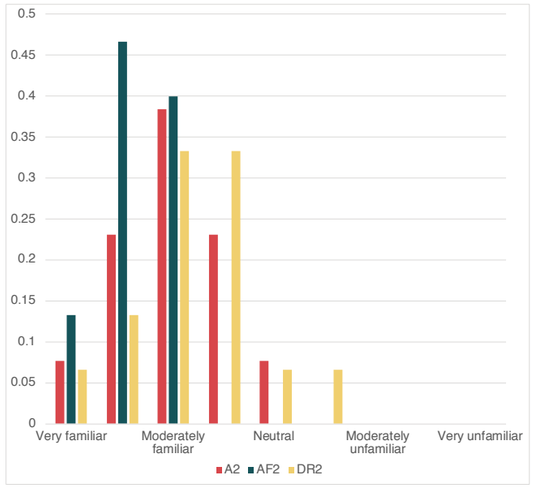


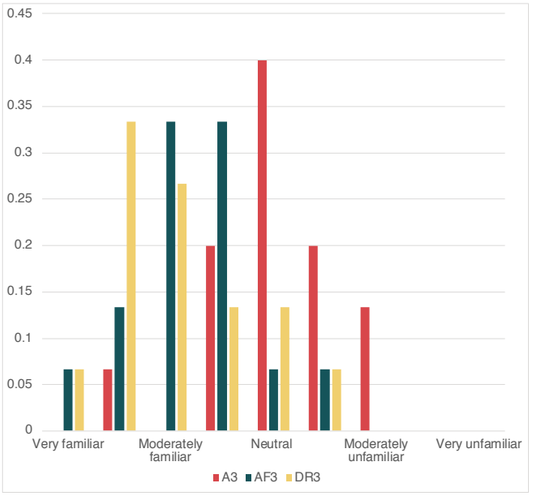




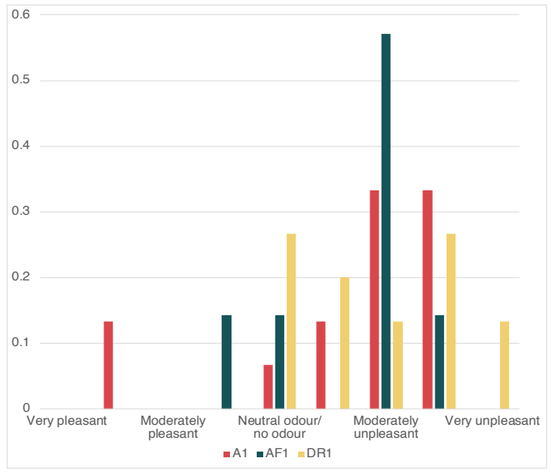
Familiarity

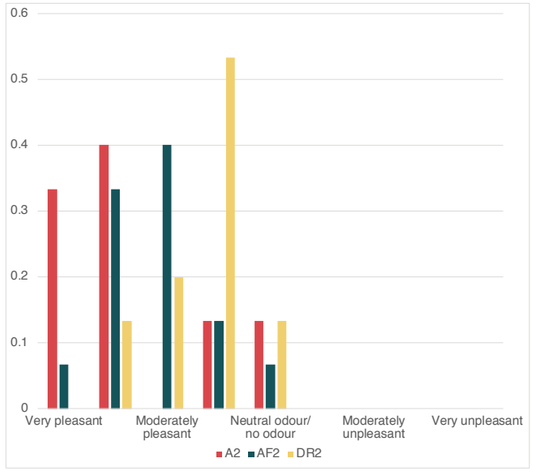


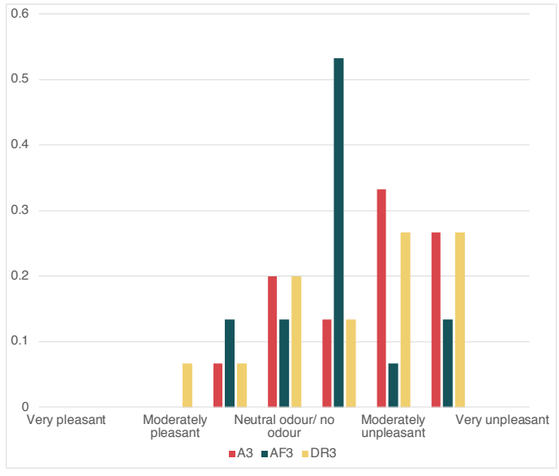




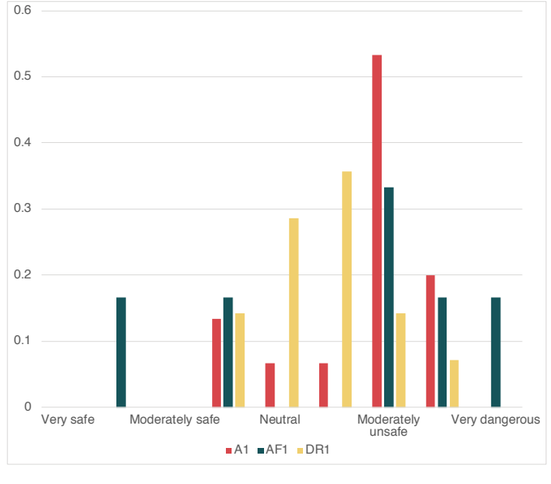
Hedonic tone

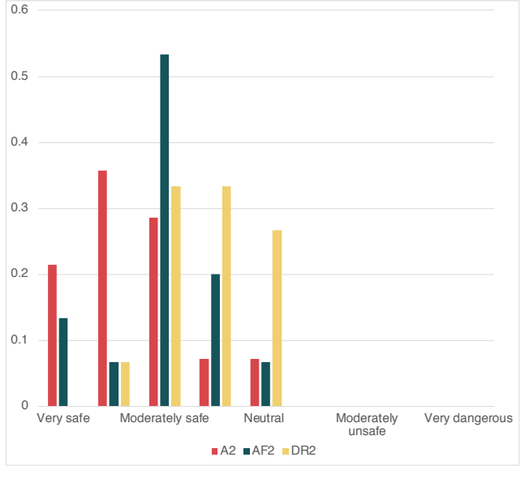


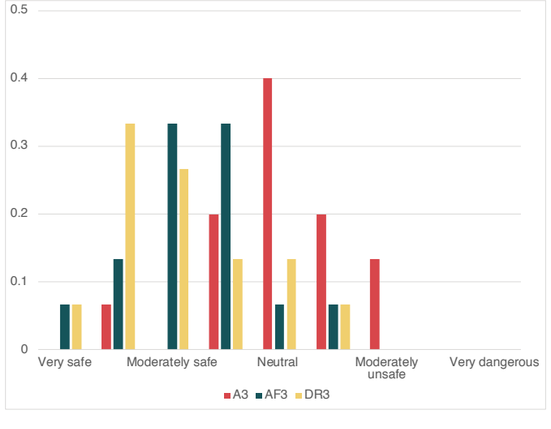




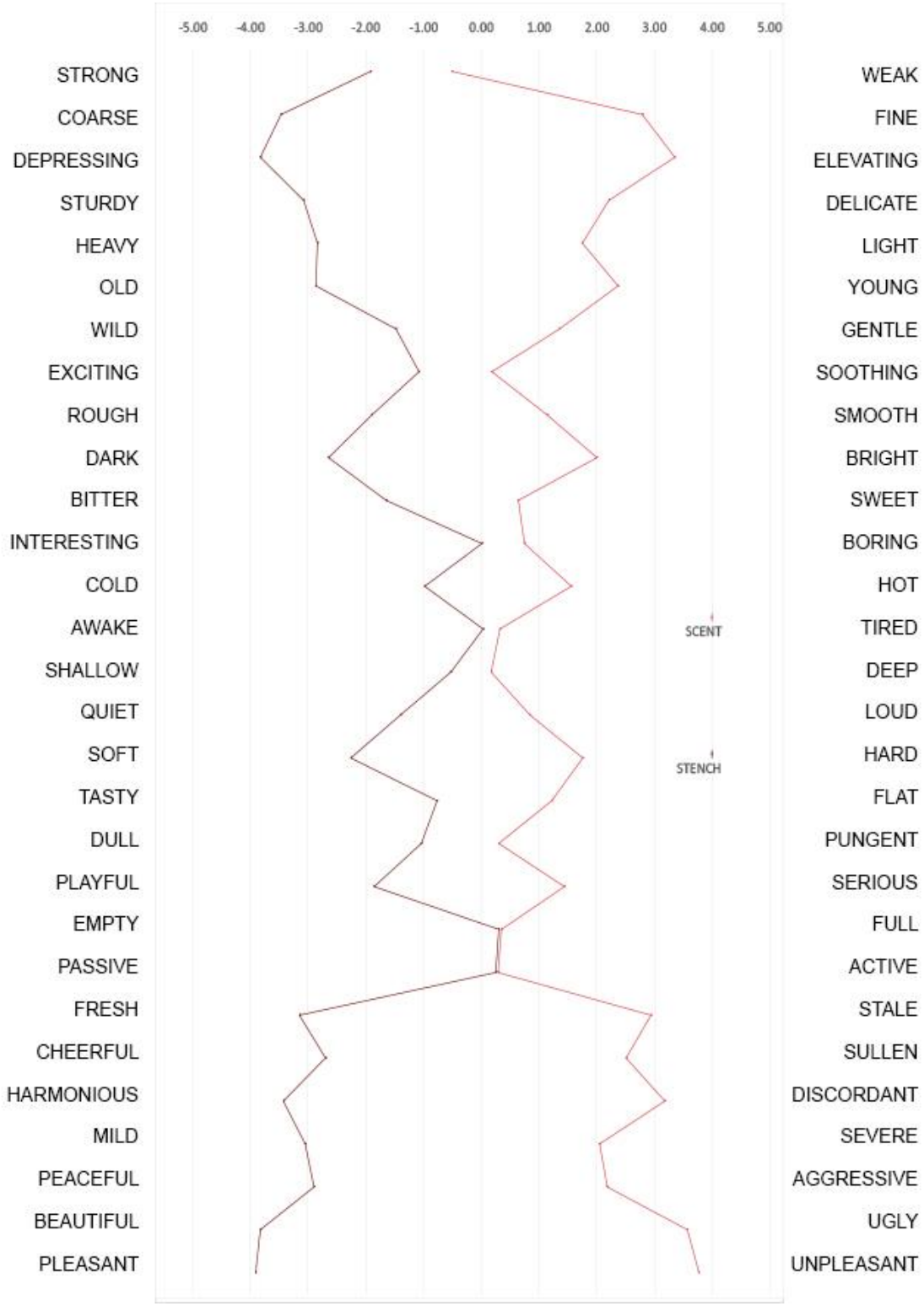
Safety







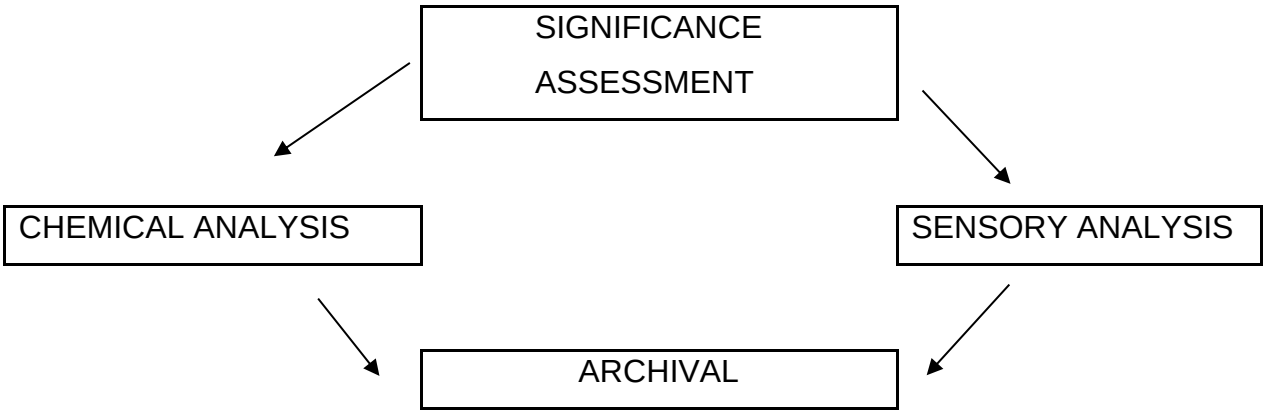
16.3.7 Polarity profile references



(Deutsches Institut fur Normung E.V. (DIN), 2010)

16.4 APPENDIX IV

16.4.1 The Smell of Heritage research framework



STEP 1: SIGNIFICANCE ASSESSMENT

Significance of a smell establishes its value as heritage and importance that it is documented. Criteria for assessing significance have been adapted from the guidance in place to determine the national importance of monuments (Historic Environment Scotland, 2019).

Following the HES model, some of the aspects that help determine the cultural significance of a smell are

- Intrinsic characteristics: how the smell of a heritage artefact or space contributes to our knowledge of the past. An example of a questions to evaluate this would be ‘Does this smell contribute significantly to our understanding or appreciation of the past, or has the potential to do so?’
- Contextual characteristics: how a smell related to our existing knowledge of the past. An example of a questions to evaluate this would be ‘Does the odour source or the setting help us understand the historical relevance of the smell and its connection with the past?’
- Associative characteristics: how the smell relates to people, practices, events and/or historic and social movements. An example of a questions to evaluate this would be ‘Is/Was this smell associated with historical, traditional, social or artistic figures, events, movements and/or practices?’.

STEP 2: CHEMICAL & SENSORY ANALYSIS

Once the significance of a smell has been established, analysing it is essential to gain understanding, obtain comparable data and document its authenticity.
This phase of analysis comprises:

- Chemical characterisation to identify odour-active volatile organic compounds. This is achieved with various methods, as described in the methodology and experimental sections of this work. Briefly, and depending on the type of smell, location/source, intensity and other factors, sampling can be done using headspace solid phase microextraction (HS-SPME) or headspace using carbon-sorbent tubes followed by thermal desorption (HS-TD). Analysis is performed using (but not limited to) gas chromatography-mass spectroscopy (GCMS) or gas chromatography-time-of-flight-mass spectroscopy (GC-TOF-MS).
- Smell is a perception, and characterisation of it by the human nose complements the data obtained using an instrumental detector. Sensory evaluation is done using trained analysts in gas chromatography-olfactometry (GC-O) and expert and non-expert odour-evaluation panels using Likert-type scales to record several variables such as odour character via descriptors, intensity and hedonic tone.

STEP 3: ARCHIVAL

The final step is designed to document the findings in a holistic way, allowing for a clear visualisation of the different types of data (for example, in an odour wheel) and accounting for risks of reductivity by complementing it with other metadata such as stories of personal significance in relation to the smell, associated visual, auditive or tactile information, etc. obtained deliberately or incidentally during the analysis phase.
In order to preserve the smell, a validation test can be conducted, in which a recreation following the data obtained during the analysis phase should be chemically and sensorily evaluated with similar results to the original smell. The authenticity of the smell cannot, however, be evaluated in the same way, as perceived authenticity depends on other factors and there is some evidence that an authentic olfactory experience can be achieved with an interpreted smell which does not bear much chemical similarity with the original.

17 Funding

This research was funded by UK EPSRC Centre for Doctoral Training in Science and Engineering in Art, Heritage and Archaeology (SEAHA) and by the National Trust. I am very grateful to both.

18 Acknowledgements

I would like to thank Prof. Matija Strlic, who was my main supervisor during the PhD, for his constant support, encouragement and for asking all the difficult questions. Many years ago, Matija's fantastic presentation on the smell of books was the revelation that led me back to research. For that inspiration, and the opportunity to do so in the best company, I am truly grateful to him.

My second supervisor in this project was Prof. Susanne Kuechler, head of the department of anthropology at UCL, who contributed with precise and original comments at key stages in this research, encouraging me to look for meaning in unexpected places. Thank you, Susanne.

I've enjoyed working at Knole and feel lucky to have been so supported both professionally and financially by The National Trust from the very beginning of this project. I thank Dana Goodburn-Brown for her brief but impactful mentorship; Siobhan Barratt and Katy Lithgow, who also supervised this PhD, for seeing value in this research and facilitating access to collections and spaces; the team at Knole's conservation studio, who saw a giant picture of me in a corner for the past four years, for their cheerfulness and interest, also to Rebecca Malkin, Michaela Hall, Martha Infray, Alex Paton and Lucy Atkinson, in addition to the volunteers working in the house and the visitors who completed surveys, for facilitating my study.

Thanks to Ton van Harreveld, industry supervisor of this project, for being a wonderful reference on all things smelly and an exceptional interlocutor on everything else. In addition to Ton, I am indebted to the team at Odournet, especially to Carmen Villatoro González, the most talented and enthusiastic GC-

O lab companion, who also showed me the value of an experimental approach to odour reconstruction.

Thanks also to Luciano Vera, a knowledgeable and imaginative thinker on odours and how we deal with them, for sharing so much knowledge and technical expertise with me, and for confirming that some scientists are also dreamers.

I would also like to thank my board of advisors, who provided essential support towards the end of the project: Sarah McCartney, who created the historic library interpretation and helped me test it with endless energy and cheerfulness, and Simon Gane, for his helpful suggestions on smell interpretation.

I would like to extend my thanks to Jo Wisdom, librarian at St Paul's, for facilitating access to the library for tests and engagement. During my visits, Jo also generously shared bibliographic jewels that I would not have otherwise found. Thanks also to Magdalena Buchczyk, for her careful reference suggestions, which were the piece the puzzle was missing.

The Birmingham Museums and Art Galleries (BMAG) was the first venue where I explored the role of smells in heritage. I am grateful to Simon Cane and The Birmingham Museum Trust for giving me that opportunity and financial support, and to Deborah Cane and her team for facilitating the research.

For the mould study, I collaborated with Prof. Tomasz Sawoszczuk from the Department of Microbiology of the Cracow University of Economics. I am grateful to him and his colleagues Jerzy Szakiel and Paweł Turek for their role in this investigation.

I would like to acknowledge the help received from the UCL Institute for Sustainable Heritage, and especially from the Heritage Science lab. Thank you to, Mark Underhill, Miriam Wright and Mark Kearney for your patience and encouragement while I got acquainted with GC-MS.

Heritage Science is an exciting field, where projects are vastly different from one another, so a PhD can get lonely. I've been lucky to have shared a lab and field trips with an exceptional cohort of students from SEAHA. Thanks to Keats and Hend, Scott and Natalie, Yun, Carolien and Lucy for their company, support and inspiration; you've made this time pretty special.

In the past four years, I have been excited to meet other researchers who had their own take on smell and culture and were generous enough to discuss it with me. Thanks to all of them, especially Kate McLean, who cheered me on and helped me design the odour boxes, and Caro Verbeek.

This final version of the thesis has had few but key improvements from the one I defended in the Viva. I thank Dr Katherine Curran and Prof. Barry Smith, my two examiners, for your precise comments that led to this work becoming clearer and, hopefully, better.

The familiar scents are the ones we keep coming back to: I thank my parents, Jorge and Silvia, for the bitter aroma of mate in the mornings and for showing me resilience, each in their own way; and Luci, Lore, Joni and Pablo, my siblings, the only people who share the smell memories of my childhood in Entre Ríos.

I am grateful to the publications who took interest in my research and the press who found readers for my findings. I also appreciate the efforts of those who found the ideas in this thesis interesting and provided a forum so I could share them. And lastly, I would like to say thank you to all the people who wrote me an email, left a comment on a press article, tweeted at the Smell of Heritage account, called a radio show when I was being interviewed or waited after a presentation to share with me the story of that smell that they once found and they have never forgotten.