Interpreting digital images beyond *just* the visual: crossmodal practices in medieval musicology

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Abstract

We argue that high-resolution naturalistic digital images of physical objects are oriented to in a very different manner than other visual representations such as 'inscriptions' which are manufactured by black-box devices in order to transform phenomena into diagrams, or 'rendering practices' where scientists visually transform the meaning of objects and events using repre- sentational techniques to select information and simplify its presentation. We show that medieval music scholars engage with high-resolution images of physical objects through crossmodal practices relying upon the intercon- nected senses to examine a variety of properties held within physical objects when they are displayed within digital images.

Keywords

crossmodal practice, visual culture, digital humanities, medieval music

Introduction

The scholarly study of medieval music manuscripts has traditionally required that musicologists travel to libraries and museums where the artefacts of interest, the complete manuscript or fragments of manuscripts, are physically held. However, with the introduction of digital image archives these scholars now have the ability to conduct much of their research through both the inspection and manipulation of digital images. When digital images are used as primary research objects skillful technical work is conducted in order to draw out and expose visual information that was not previously accessible. This kind of work is conceived of as encompassing a set of scientific practices especially when manipulating, marking, categorizing and comparing features that reside within images using graphics editing software. In addition to these obvious practices where computerisation is used as a way to engage with information, we also find that medieval musicologists engage in rather non- obvious practices related to the use of technology to make sense of a physical object's attributes as depicted within digital images that goes beyond the visual. We find that the scholars draw upon a number of different modalities to interpret what might be the tactile qualities of a manuscript's parchment weight

and texture as well as the auditory qualities represented in musical notation that denotes melody, rhythm and pitch. In this way, other sensory modalities are recovered and integrated into their visual analysis of digital images making activities around image interpretation and visual practice a broadly concerted effort involving not just a single sense but many senses.

The interconnected senses

The concept of 'multisensory experience', and research related to it, is concerned with developing an understanding of the role the senses play in the mediation and interpretation of phenomena. Research in this area investigates the *integration* of semantics with the other senses to explore the "different points of apprehension, interpretation [and] knowledge construction" that make up the "dynamic cross-relationships" between the senses (Porcello et al. 2010, 57). Interest in this area of research has existed in anthropology for some time beginning with investigations into culturally-specified 'sensory codes', which are the socially-acquired meanings attributed to sounds, smells, tastes and touch (Levi-Strauss 1969, 147-63). Investigations into sensory codes continues to be an important research topic within anthropology and sociology (Howes 1991; Classen 1997; Low 2005; Pink 2009) as well as for the interdisciplinary field of sensory studies (Sensory Studies 2011) where scholars investigate sensory experiences in a wide variety of settings in order to understand how their socially-acquired meanings inform perceptual understanding.

More recently, within Science and Technology Studies (STS) scholars have discussed the manner in which scientists engage in very specific types of 'body-work' when participating in discourse about experimental data and making models (Myers 2008). Additionally, the non-visual dimensions of embodied knowledge have been discussed specifically in relation to the interpretation of auditory phenomena in laboratory settings (Mody 2005). Also, within Computer Supported Cooperative Work (CSCW), embodied actions such as gesture, gaze and bodily orientation are investigated to understand how communication, collaboration and interaction might be mediated through computational devices (Suchman 1993; Robertson 1997; Luff et al. 2000). Finally, ethnomethodologically-informed studies of work examine the embodied and collaborative practices that facilitate the mutual understanding of sensory experiences such as texture and taste when producing materials in a laboratory setting (Goodwin 1997).

In the research area of the 'digital humanities' (Schreibman et al. 2004), technologies are being designed that integrate computational tools and techniques with the more traditional scholarly activities found in history, philosophy, literature, art, dance and music. As a result, computing activities are embedded alongside the analytic, critical and speculative methods

employed by scholars in the analysis of texts, artefacts, movements and sounds. And so, as scholars' research objects increasingly become digitised and made available within web-based digital archives and virtual workspaces, we find that some of their research practices are being transformed as well (ibid; Terras 2006, de la Flor et al. 2010b). As part of a programme of empirical research studying scholarship in transition as new technologies are taken up across a variety disciplines (Jirotka et al. 2005; de la Flor et al. 2010a, de la Flor et al. 2010b), this paper discusses how new computational technologies are transforming musicologists' research practices through the manipulation and inspection of digital images which serve as proxies for the inspection of actual physical manuscripts. So rather than relying upon simulations or visualisations of phenomena and objects, these scholars rely upon the study of high-resolution digital images that depict the actual physical objects themselves. While musicologists' increasingly use digital images to study physical objects, we investigate the ways in which this affects both the reading and interpretation of medieval music manuscripts.

We find that musicologists engage in the obvious computing activities when they use image editing software to manipulate, mark, categorize and compare features that reside within digital images (activities associated with scientific practice). However, we also find that they engage in rather non-obvious practices as they draw upon *the interconnected senses*, the visual, auditory and tactile, to examine the physical properties of objects (their condition) and the features found within them (their content). In this way, musicologists' analysis of objects and features displayed within digital images is mediated through, not only the technology itself, but also through their attentiveness to their own inter-related senses in the interpretation of the properties and qualities of an object. So within the wider, more general discussion of visual culture, we can say that these practices are unlike the use of 'inscriptions' that are manufactured by black-box devices in order to transform phenomena into diagrams and where the markings are then translated by scientists to support of scientific discourse (Latour and Woolgar 1979), and also unlike 'rendering practices' where scientists visually transform the meaning of objects and events using representational techniques to select information and simplify its presentation in order to construct a more visible, knowable or 'docile object' (Lynch 1985, 43). In this paper we discuss how medieval music scholars engage in *crossmodal practices* where other sensory modalities are recovered and integrated into their visual analysis of digital images making activities around image interpretation and visual practice a concerted effort involving not just a single sense but many senses.

On the one hand, digital images afford a kind of durability that enables detailed visual inspection and manipulation which would otherwise be impossible (e.g. adjusting a manuscript's gamma levels and extreme magnification) or that would permanently damage or destroy the physical object (e.g. digitally peeling away features to reveal objects underneath). On the other hand, musicologists orient to visual images beyond their assumed exclusivity as

"observational and objectifying tools" (Pink 2009, 99), where the visual is isolated from the other senses, and instead draw upon the integrated senses (visual, tactile and auditory) to interpret the condition and content of medieval music manuscripts. Assertions of 'ocularcentrism' (the privileging of vision over the other senses) in the investigation and reporting of both the material practices of visual cultures and in the analysis of a community's practices, knowledge production and socially-acquired meanings has been raised as an issue across interdisciplinary boundaries (Howes 1991; Classsen 1997; Pink 2009; Porcello et al. 2010). Because the semantic and the visual are the most obvious modes of conveying understanding and information these tend to be the focus but they may not necessarily deliver the entire story of how people make sense of their world (Low, 2005). As our experiences are increasingly mediated through digital technologies and where currently our primary route of access into virtual reality/research spaces is through the visual, the nature of embodied experiences as one participates within those spaces needs to be taken seriously. These hybrid interaction spaces have been found by some researchers to be places where "the visual is treated as inseparable from the tactile, kinesthetic, and proprioceptive" (Porcello et al. 2010, 58-9). We have also found that the visual is deeply interconnected with the other senses as medieval musicologists inspect digital images using computational resources *alongside* the analytic, interpretative and speculative techniques they rely upon to understand the physical objects that they display.

Methodology and approach

To investigate embodied practices around digital image analysis we conducted interviews using a semi-structured format with seven medieval music scholars distributed across three continents (Europe, North America and Australia). From senior scholars who began their careers in the early 1960s to emerging scholars just starting out in the 21st century, informants consider themselves to be enthusiastic early adopters of digital technologies in relation to their research practice.

In addition to interviews, we facilitated one focus group with five scholars to discuss the ways in which digital images are used in the analysis of medieval music documents. Finally, we conducted two ethnographic fieldwork sessions with a pair of medieval musicologists, a scholar and her student, to acquire a more detailed understanding of how they use digital images as part of their routine research practice. During the fieldwork phase, audio-visual elicitation techniques were utilised to discuss selected video fragments with the scholar and her student in order to understand both the details of activities as well as the technical language they used. We draw upon ethnomethodology (Garfinkel 1967) and an analysis of conversation (Sacks et al.

1974) in the study of the video recordings taken during observational fieldwork. This exploratory research study took place over a 12-month period from early 2010 to early 2011.

For this paper we refer to the interview data to discuss how computing activities enable the detailed inspection and manipulation of digital images. After which we draw upon video fragments taken from fieldwork studies that reveal how interpretative activities related to 'computational seeing' are interconnected with other senses specifically where the musicologists attempt to recover tactile and auditory understandings related to the physical manuscripts displayed within digital images.

Medieval musicology

Medieval musicology is the study of music composed and performed between the 6th and 15th century, from approximately 500-1400 (cf. Hoppin 1978). Almost all of the extant evidence of music from this period comes from handwritten manuscripts produced by scribes. Very few of these manuscripts still exist in their complete form, although more survive as damaged and fragmentary pieces. In many cases, fragments have been preserved only because they were re-used as bookbinding material or for other purposes such as chair stuffing, papering for ceilings, hat-box linings and padding for musical instrument cases. Medieval musicologists are interested in these source manuscripts for a variety of reasons. For instance, the content of these materials enable scholars to study both secular and sacred music within a specific time period and draw out its relationship to historical events. They also compare compositional styles and notational variation, as well as conduct analyses of song in courtly contexts to understand how it may have been used to communicate political ideas and create coherence within a community. Additionally, scholars attempt to reconstruct fragmentary pieces with reference to other manuscripts and fragments. Finally, the layout and notational style of manuscripts is of great interest for understanding how to read and actually perform these musical works today.

Traditionally, medieval musicologists conduct their work by analysing the original physical manuscripts (Fig. 1), using a magnifying glass to inspect details and a ruler to measure its size. They also inspect physical characteristics such as leaf textures, bookbinding, and ink pigments. Additionally, musicologists are interested in understanding the sounds that a series of musical notes might represent. They may also reference other materials associated with a manuscript such as facsimile books (high-quality photographs) or microfiche (black and white or colour negatives approx. 25 times smaller than the original manuscript's size accessed through a reading machine and then magnified).

Medieval musicologists inspect both the *content and condition* of these manuscripts and increasingly high-resolution digital images of them are being made available through digital image archives. In many cases, archives such as The Digital Image Archive of Medieval Music

(DIAMM 2011) and others, were originally set-up to support the conservation of medieval polyphonic music manuscripts to ensure that their contents may still be viewable in cases of their loss from natural degradation, theft and geopolitical difficulties to gaining access. However, increasingly musicologists are using these online archives as research tools. In what follows, we discuss how medieval musicologists orient to the use of digital images when conducting research related to the analysis of medieval manuscripts and fragments.

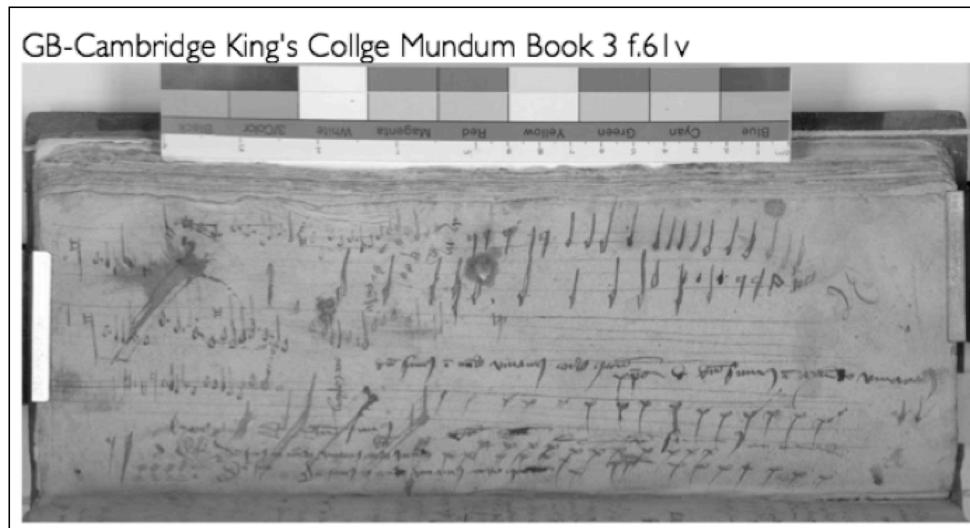

Figure 1. Digitized medieval manuscripts, the DIAMM Handbook.

Inspecting and manipulating digital images

Within the DIAMM archive, for instance, each image includes the following elements: a manuscript page or fragment, a colour patch and ruler (Fig. 1). Both the colour patch and the ruler are placed alongside the manuscript item serving as reference points that provide indications of its actual physical appearance: these are used by scholars to orient to physical objects as they are portrayed in digital form. The ruler provides a sense of the item's actual size and the industry-standard colour patch assists in determining if a scholar's computer monitor is calibrated correctly ensuring that they see colours accurately.

Through this display, each leaf or fragment of a manuscript is extracted from its context within a material codex and its surrounding pieces and is presented as a discreet scientific specimen. This is particularly interesting in light of two well-known accounts within STS of scientists who also use visual representations of physical objects. One has characterized their use as leading to, in the case of astronomy, a transformation of "observational field science to an image-processing laboratory science" (Knorr Cetina, 1992, 117), and in the case of the UK systematics community, as provoking resistance where existing material culture influenced negative responses to an engineered virtual culture (Hine 2006).

Both of these concerns - the transformation of fieldwork approaches into a laboratory-type science, and points of resistance to the introduction of new technologies are important topics in debates around the introduction of computational imaging within a range of research disciplines. In our study the researchers we interviewed appraise the properties of digital images as facilitating and enhancing their research. For instance, one informant noted that he can:

> Probably do 80, 90% of everything through the high-res digital images and only for the remaining 10, 15, 20% you need to see the manuscript. (Medieval musicologist A)

Prior to the availability of digital image archives, gaining access to source materials was once, and often still is, difficult especially in cases where the manuscript is severely degraded and handling might destroy it further, or when strict requirements are imposed on independent scholars who are not affiliated with an institution. Also, when scholars are based in continents far from Europe (where many the physical objects are held) some rely upon digital images as their primary research objects. In one case, a scholar we interviewed has tailored his research towards investigations of the scribal process focusing specifically on the study of erasures which can be detected through digital image manipulation. This medieval musicologist tells us that:

> The traditional ways of detecting erasures is actually getting in there and consulting the manuscript. Now that is increasingly becoming more difficult … it was very useful to actually have the color images to work with because something the computer technology allows someone to detect are erasures through the manipulation of the image gamma. That's the image gamma or the images levels, one can actually bring out what would normally be invisible, literally invisible on the page, to essentially a very clear indication that there's an erasure there. (Medieval musicologist G)

In one manuscript, the scholar discovered that the scribe made a substantial erasure at a point that dramatically changed the meaning of the musical notation. This allowed him to form an entirely new reading of the scribe's activity which was instrumental in forming a new interpretation of the participation of that individual in the production, history and reception of the manuscript. The details of how to conduct technical computing activities are shared amongst musicologists informally through *ad hoc* emails or in-person tutorials and also through the distribution of the DIAMM Digital Restoration Workbook (Craig-McFeely and Lock 2006). This workbook is widely known and distributed within the community and provides step-by-step guidance in the implementation of different technical combinations to produce digitally restored images through the manipulation of colour, brightness, contrast, sharpness, as well as techniques for the realignment of objects such as staves using off-the-shelf commercial software.

For digital archives like DIAMM that not only store digital images but also engage in resource creation through digital image capture activities, taking extremely high-resolution photographs is essential to making possible the application of post-processing techniques that

make visible content that could not be seen otherwise. In addition to image manipulation, musicologists conduct detailed comparisons of digital images to trace the careers of scribes as they moved from place to place. As one scholar explained:

> The scribes of the Middle Ages worked really hard to be anonymous. If somebody started taking over the work of another scribe on page 50, the scribe would copy the handwriting of the other person. They would try not to use their own. And so you end up looking for very, very small, subtle, telltale sort of habits that you can only see with really great quality photographs, and then I'm able to see how various manuscripts connect with each other. (Medieval musicologist E)

Additionally, because the physical manuscripts and fragments written by the same scribe are often geographically distributed, those that have been digitized and made available within digital archives make it possible for scholars to compare them across various libraries and museums without the need for extensive travel which may otherwise take many months to complete at considerable expense. In this way, historical overviews of a particular period are accelerated as another musicologist confirms with an example from the 16th century (there is interest in manuscripts written immediately after the medieval period because their content includes medieval music):

> Say I want to look at music manuscripts in the first decade of the 16th century. I can now pull it up because DIAMM metadata has a date field, so I said between 1500 and 1510, and I get a list of 80 manuscripts across Europe which were produced between 1500 and 1510. And then with some ease I can either look at the images in DIAMM or I can find the images elsewhere. And so give me a week or so and I can give you that overview and then you can search that in all sorts of ways. Or on your screen you can actually put an image from a manuscript from Cyprus and an image from a manuscript from St. Petersburg, an image from a manuscript from St. Andrews side by side. And that way you can see things, you can draw direct comparisons which was, I tell you, it was not always possible and what people did with photography, with microfilm, with just a lot of traveling. But it's now come within reach of a lot more people. (Medieval musicologist A)

This accessibility has in some way democratized scholarship in medieval musicology where those in universities who may not have funding to undertake long excursions, independent scholars not affiliated with an institution and choir enthusiasts have in some, but not all cases, free access to high-resolution photographs of source materials. However, even with the acceleration of research facilitated through ease of access to digital image archives, one scholar talked about the continued pressure to work in more traditional ways:

> I do feel pressure, for instance there's this notion in the field that you can always get more out of seeing the original than seeing a digital image of it. And I do feel pressure to work more with originals than with the digital images because of the traditions in the field. Whereas frankly, there are times that that's really important, but for the most part I do feel like I get more out of sitting, using these images on my computer. I do feel like there's a certain pressure that that's not what top scholars do because that's not what top scholars did 25 years ago. (Medieval musicologist E)

The tension between traditional and emerging forms of research practice is tied to the expectation that serious scholars actually handle and view physical manuscripts as a senior musicologist explains:

> You obviously need to have seen the physical thing to get a sense of it. And yeah, there are things that you can only see on the original, including for example, the structure of the manuscript, the way the leaves are folded and sewing and that kind of thing. (Medieval musicologist B)

Whilst recognising this tension, scholars nevertheless acknowledge the new analytic possibilities digital images provide:

> Digital imaging opens up the possibility for manipulation in ways that can restore stuff that is no longer visible. For me the magnification, extreme magnification is very useful. Being able to zoom in much further than you could even with a magnifying glass. Often, it allows me to see things I couldn't, that I wouldn't be able to read or that I can read better from a massively magnified image. (Medieval musicologist F)

In addition to the benefits, these scholars are also keenly aware of the limitations of digital images. Firstly, they cannot appreciate the whole book as an object in its own right when viewing a series of separate images of each of its pages. These discrete images have been extracted from their context within a codex making it difficult for musicologists to get a sense of a book's construction especially how the pages are gathered into quires. Knowing the details of its construction enables scholars to tell if a page was part of the original manuscript or if a new page was inserted into the original leaves. Even though recent manuscript catalogues usually list this information, the majority of manuscripts were catalogued many decades ago, often in the 18th or 19th century, making it such that these details are obtainable only through handling the manuscript itself. Secondly, scholars rely upon their sense of touch to feel the parchment (or paper in later manuscripts). The thicker and rougher it is, the cheaper it would have been. Conversely the thinner and smoother it is, the more expensive. Knowing these details may reveal the status of the music itself when it is associated to the quality of the parchment that it was written upon. In addition it might also suggest the likely context of its production.

Also, when viewing digital images scholars can't really distinguish between a mark that is the result of scraping or rubbing (e.g. an attempt to erase something previously there) or a mark that indicates damp or some other stain. They usually determine this by feeling the parchment's texture where such marks might tell them something interesting about the manuscript's history. Finally, when examining manuscript fragments scholars may be able to spread the different segments out upon a table to try to fit them together and determine what pieces might be missing. This is more difficult to do with digital images because aspects of the feel of the parchment as well as the shape and size of the pieces would come into play. In regards to making sense of information associated with the sense of touch one scholar tells us that:

> We can appreciate this partly through images, you saw how we can sometimes tell the parchment is thin from seeing the show-through of ink from the other side, but it's much easier to appreciate this difference if you can touch it. (Medieval musicologist F)

This reliance upon senses other than, and in addition to, the visual in the interpretation of physical objects has implications for scholars who investigate those objects through digital images. In the following section, we discuss some of these implications drawing upon audio-visual fragments taken from our observations of medieval musicologists at work. We reveal how the scholars employ what we refer to as 'crossmodal practices' in their analysis of physical objects as they use digital images to interpret those objects. First, we show how they formulate workarounds to discern what might be tactile qualities of a manuscript's parchment and second, how they make sense of notational details written into manuscripts through talk about its rhythmic behaviour; the way it might sound and the way it may have been meant to be heard.

Discerning the physical qualities of a manuscript

Some have described sensory recollections (e.g. remembering the specific tactile feelings and qualities of an object) as an avenue into the 'sensory imagination' used to ignite one's memory in order to re-experience specific sensations that a photograph, object, setting or event may conjure up. These are often treated as abstract cognitive processes that only the imaginer can know, also referred to as the 'embodied imagination' it may only be accessed through self-reporting mechanisms such as interviews or first-hand phenomenological accounts (Ihde 1976; Pink 2009). However, we find that what are often framed as cognitive phenomena, may also be made visible through observation of the practices and interactions that occur within social settings (cf. Lynch 2006). In the example below, a medieval musicologist (Pam) and her student (Jeremy) participate in the inspection of a digital image so that they might recognise and evaluate visual depictions that could provide evidence related to the tactile qualities of a manuscript:

Pam: **There's terrible show-through of the decoration from the other side**
there ***((pointing to the area))***
Um, which suggests that the parchment is very thin.
((rubbing her fingers together))
But we'd actually have to touch it to verify that.
[
Jeremy: **↑ Yea.**

Figure 2. Teaching the skills necessary to interpret visual traces within digital images.

Pam points to the visual features within the digital image to highlight the markings that suggest the parchment's thinness. By rubbing her fingers together, she makes visible to her student the activity associated with feeling parchment texture. Interpreting what the show-through of inks might indicate within the digital image enables the pair to recognise and to speculate about sensory qualities other than the visual in their analysis of the manuscript. From this activity the student learns how to interpret 'show-through' enabling him to become sensitive to what might be the tactile qualities of the physical object.

During the activity, the scholar remains mindful of the tension between the inspection of digital versus physical objects and so adjusts her initial analysis with a cautionary note that the parchment would need to be physically touched to verify this interpretation of visual traces. We see how the visual can be interconnected with the other senses in the manner that Pam instructs Jeremy specifically in the application of the 'sensory imagination' as they orient to visual traces in a way that allows them to speculate about the parchment's texture. This strategy, interpreting 'show-through', is a workaround formulated by the scholar when only a digital image of the physical object is available. Such constraints invite us to consider other ways they might recognise and evaluate visual depictions in their analysis of digital images.

Distinguishing smudges from holes within the parchment

Scholars told us during interviews (see above) that distinguishing marks which appear on a manuscript's parchment as either a scribe's erasure which may result in a hole developing over time, or some kind of stain, requires that they feel its texture. However, when viewing digital images of such marks the scholars we observed apply a workaround to distinguish a smudge

from a hole when they cannot actually touch the physical object. Because digital images present three-dimensional objects in two-dimensional space they flatten the appearance of physical objects and so the scholar and her student develop a novel approach for interpreting marks within these flat images:

Jeremy: **I'm going to take it that these markings aren't- are just marks rather than anything else. Cause they don't appear in this chant book, so-**

Pam: **Should we just zoom right in and see if we can see those-**
>wait for the resolution to sort itself out<.
They might even be holes might'en they (.) some of them.

Jeremy: **Yea, if we look at the other side we might be able to see if=**

Pam: **=There's a hole in the equivalent place.**

Jeremy: **Yup, which would be on the left-hand side.**

Pam: **Yea, good thinking.**

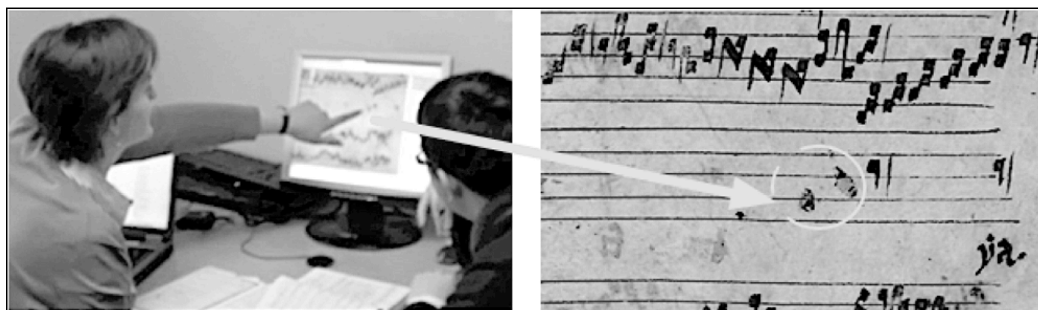

Figure 3. Developing a workaround to distinguish marks that appear on the parchment.

Jeremy identifies markings on the parchment which appear to be something other than musical notes. Pam suggests they zoom into the area to get a closer look proposing that the marks may even be holes. The pair then collaboratively formulate a way of making the mark more intelligible with Jeremy suggesting ("if we look at the other side we might be able to see if-"), and Pam interjecting ("there's a hole in the equivalent place"). During this exchange they develop a workaround that may help them to distinguish a smudge from a hole. Upon visually inspecting the respective digital images taken of each side of the same parchment leaf they hope to see whether or not a feature on one side is visible at the same place on the other side of the same leaf:

Jeremy: **I can't see any visible-**

Pam: **(It) would be somewhere wouldn't it**

Jeremy: **Yea**

Pam: **Mm, ok so it's a smudge rather than a hole (.) Some kind of stain.**
There's obviously considerable staining=

Jeremy: **=All over=**

Pam: **=In various parts. And also quite a lot of rubbing of some of the inks.**

Jeremy: **Yea.**

As they inspect the digital image of the other side of the parchment leaf, Jeremy and Pam agree that there is no visible mark at the same position. Pam concludes that it is a smudge rather than a hole and bolsters her assessment by saying ("there's obviously considerable staining"). These other unambiguous markings indicate staining in other areas and so provides Pam and Jeremy with supporting evidence. As in the previous example, the musicologists collaboratively strategize to develop a workaround for inspecting three-dimensional objects as they appear within the flattened two-dimensional space of digital images. Identifying a mark as a smudge or a hole within this virtual workspace requires that they compare two digital images of the same leaf (front and back) and in this case, the absence of a matching mark on the other side indicates something else about its texture, that the parchment has *not* been perforated and so it is not an erasure made by a scribe but rather a smudge or stain which has entirely different implications for their interpretation of the manuscript.

Making sense of musical symbols

The scholar and her student make assessments about physical objects (parchment leaves) with digital images by strategising workarounds. They also use them to gain access to the music written upon the leaves where digital images provide access to temporal phenomena written as auditory symbols (musical notes) allowing the musicologists to translate a sequence of notes into sounds that convey their rhythm and melody. The complexity of translating musical symbols into sounds has been described as a cognitive process where musicologist and musicians use their 'inner hearing' to imagine what notes might sound like through accessing the 'mind's ear' (Bailes 2009, 41). However, when we take account of musical performance as social practice (Cook 2001) an opportunity presents itself for us to move away from framing the activity of translating musical symbols into sounds as a cognitive topic. This relationship between musical notation and performance and the activity of translating symbols into sounds is a complex activity:

> Of course the student of linguistics uses the art of speech to study speech, whereas the student of music uses speech to study another art, whose resemblances to and differences from speech are not easy to trace. (Seeger 1951 quoting Bloomfield: 245)

Music can be talked about through verbal discourse as well as through *talk about sound qualities* where vocalizations of timbre, melody and rhythm act as descriptions of *musical*

behaviour (Feld and Fox 1994). There is commonly an "intertwining of speaking and musicking [at the] site of social interaction amongst musicians" (Feld et al. 2004, 322) and in our final example, the musicologists talk about musical behaviour as they compare the rhythms of two 13th Century polyphonic pieces of the same 6th Century plainchant - *Alleluia Dies Sanctificatus* (Alleluia for Christmas day).

Here, Pam and Jeremy want to understand the rhythmic differences between the two pieces as written in the Florence and the Cambridge manuscripts[1]. The scholars would like to know if they possess different rhythmic qualities and if they do what its significance might be:

Pam: **It's the same notes isn't it but differently ligated (.3) umm**
(1.8)
would that change the way you read it do you think?
[
Jeremy: **Ummm**
Well yea >°cause it's°< ***da dum - da dum - da dum***
yea cause it would put it in the second mode.

Jeremy simultaneously taps out the pattern with his pencil while vocalizing the rhythm that he sees. Upon completing his sounding/tapping Jeremy concludes that the notational ligature (a device used to represent rhythm) would put that line into the second modal rhythm, meaning that the beats would be sub-divided differently. Rhythm in medieval music is represented in 'modal notation' where long and short durations are determined by a note's *spatial position within a group of notes* rather than with free-standing representations used today in the form of half or whole, quarter, sixteenth note, etc (e.g. 𝅝 𝅘𝅥𝅯 ♩ 𝅗𝅥 ♪). In these two manuscripts a repeated or double C is ligatured (spaced apart) differently.

Upon first glance the same notes within the two manuscripts would be read/sounded/heard differently. Pam then turns to the Cambridge manuscript to determine what its rhythmic pattern might be:

Pam: **Yea >or as he put it here<** ***dum da dum - da - dum da dum -***
da - dum da dum.

Figure 4. Sounding the rhythmic pattern in the Cambridge manuscript.

The scholars collaboratively work through the musical behaviours of each manuscript using both verbal discourse and soundings that are mutually understood for the purposes of trying to make sense of the rhythmic relationships between notes. Earlier in the session Jeremy had attempted to translate the Cambridge manuscript into modern notation and Pam asks him how he has transcribed the line:

Pam: **How does it go over there?**

Jeremy: ***dum da dum - da - dum da dum*** **(.) well, I didn't know what-**

Pam: **Some kind of rest *((laughs)) dum da dum dum***
[
Jeremy: ***dum da dum dum***
Yup.

Figure 5. Comparing rhythmic sound patterns in the Cambridge manuscript transcription.

The pair compares Jeremy's transcription, again through performed sounds, so that they might recognise rhythmic patterns. Later in the session, the seeming rhythmic difference between the two manuscripts is resolved. The scholars conclude that each scribe made different decisions for how to represent *the same rhythmic pattern*. This difference can be attributed to a rule in modal notation which states that two notes of the same pitch cannot be ligatured. So, in this case there are two options; use no ligature at all, which is what Cambridge scribe did or switch around the ligatures of the whole passage so one C note is attached to the note *before* it in a ligature and the other C is attached to the note *after* in another ligature as the Florence scribe has done. The risk of doing this is that the ligature pattern is "messed up" so that if you look at the Florence manuscript quickly one might think it was in a different rhythm. However, when viewing that line within the context of the entire musical piece the scholars identify it as being in the same modal rhythm as the Cambridge copy.

The activity of rhythmic comparison would be virtually impossible to accomplish exclusively through *language about music* and the use of musical terminology alone. Rather, vocalized descriptions of musical behaviour are produced to describe sounds directly and are intertwined with talk. In this manner, digital images of medieval music manuscripts are oriented to so that the scholars may evaluate and make sense of the rhythmic dimensions of musical

notes as they are displayed within digital images. As musical notes lend themselves to being read or sung or tapped aloud, the auditory dimensions of medieval music manuscript analysis is not integrated or embedded into the digital object which may lead to considerations of how digital images might be complimented with auditory tools in this context.

Discussion

This paper has addressed the topic of 'computational seeing' from the perspective of the 'sensory turn' where we show that the privileging of vision over the other senses may need to be reassessed in both computational interaction design as well as studies that examine sociotechnical configurations more generally. The scholars we studied are enthusiastic about taking advantage of digital objects. However, we find that they must strategise workarounds when using them as research objects in their own right. The analysis of digital images that depict physical objects is quite different to the analysis of visualisations which transform phenomena and objects in a way that amplifies, re-represents or creates information anew either through manual processes or by using complex mathematical algorithms.

Simulations are artificial where truth, falsehood and the imaginary are difficult to distinguish (Baudrillard 1994) whereas high-resolution digital images of physical objects are intended to depict 'the real'. From this we suggest that within the continuum of the real, the neoreal and the hyperreal, different visual cultures may emerge along with different material practices. In our study, depicted physical objects are the primary research interest to scholars and here the notion of *visual culture* and its associated material practices is expanded to include a more broadly conceived notion of visual interpretation that involves not just a single sense but many senses which impact upon both the reading and interpretation of medieval music manuscripts.

The ways in which medieval musicologists make sense of the properties and attributes of the physical objects displayed within digital images raises many questions. What is gained and what is lost when physical objects are displayed in digital form? When and how is the visual interconnected with the other senses when inspecting familiar types of physical objects through digital images? How are high-resolution digital images of objects interpreted if researchers have no first-hand sensory experiences of them (e.g. Mars Rover photographs, microscopic photos or satellite imagery)? These questions may hold relevance in research disciplines where computational seeing involves the investigation of real-life objects in as true-to-form as possible and where maintaining the integrity of the object within its digital depiction is critical to its analysis in digital form.

In this case study, digital images were used to *reconstitute* the material and sonic properties of physical objects. We suggest these findings contribute to a reconceptualisation of the notion of visual culture and its associated material practices, where other sensory modalities are

recovered and integrated into the visual analysis of digital images making activities around visual image interpretation a broadly concerted effort involving not just a single sense but many senses.

Notes

[1] The manuscripts' names indicate the locations where they are currently archived and not their origin. Both are thought to have been written in Paris or northern France and each is closely associated with Notre Dame Cathedral where the music is said to have originated.

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