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Dealing with the complexity deluge

VREs in the arts and humanities

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Abstract

Purpose – The aim of this paper is to review the concept of the virtual research environment (VRE) in the light of its development over the past five years, and assess its applicability to the arts and humanities disciplines.

Design/methodology/approach – Evidence from a number of case studies exemplifying the VRE approach is reviewed, and the case of a VRE in archaeology, the Silchester Roman Town project, is discussed in detail. The interpretive implications of using computers as a means of dealing with artistic and humanistic data, are highlighted.

Findings – There is a critical comparison to be drawn between VREs in the sciences and the humanities/arts. This is caused by the "fuzzy" nature of data and workflows in the latter, as compared with the more formal and definable research practice in the former. It is proposed that, to deal with this, the plan of any project which seeks to set up a VRE in the humanities should consider the research process under three headings: processes which the VRE seeks to introduce, existing processes which it seeks to undertake digitally, and processes which will be unaffected by the VRE.

Originality/value – In order to progress "the VRE" from being an artificial construct, driven by dedicated project funding, towards being an embedded part of research practice, those concerned with developing VREs need to consider the nuances of those research practices. This paper seeks to review those nuances by synthesizing data and experience from existing projects, thereby facilitating that embedding process.

Keywords Archaeology, Data analysis, Virtual work, Arts, Work flow, Research

Paper type General review

1. Introduction

The term "virtual research environment" has become increasingly common in certain sections of higher education in the past five years. However, and despite the ubiquity of network computing in modern university departments, it has yet to permeate the mainstream academic community. This is partly because the term is an artificial one, and is not itself unproblematic. If one assumes that an "environment" in this context is the digital counterpart of a research setting which does not utilize computational networks, then it must refer in some sense to a tangible infrastructure on which research is conducted electronically (bearing in mind that the internet is, of course, itself based on a physical structure of cables, computers and servers). However, the term e-infrastructure, as generally understood, carries with it certain assumptions

Much information regarding the Silchester project has been gleaned from conversations with project staff from the Universities of Reading and York, University College London, and the York Archaeological Trust. The author extends his grateful thanks for their collaboration and their willingness to share information.

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about the capacity it gives researchers, and the scholarly work it enables. As currently used in the UK, e-infrastructure is broadly synonymous with cyberinfrastructure in the US. In 2006, the American Council of Learned Societies (ACLS) report on Cyberinfrastructure for the Arts, Humanities and Social Sciences defined cyberinfrastructure as:

> [. . .] more than a tangible network and means of storage in digitized form, and it is not only discipline-specific software applications. It is also the more intangible layer of expertise and the best practices, standards, tools, collections and collaborative environments that can be broadly *shared* across communities of enquiry [original emphasis] (Unsworth, 2006, p. 6).

However, the "not only discipline-specific" aspect of cyber infrastructure expresses both its strongest appeal and its main drawback: while generating new knowledge by working across and beyond established intellectual disciplines is at the heart of "digital scholarship", the lack of a disciplinary focus with which scholars can identify is another reason why the term VRE has not established itself.

In the UK, the prime funder of VRE development and activity (or at least activity which uses the label) is the Joint Information Systems Committee (JISC). JISC's definition of a VRE, available at www.jisc.ac.uk/whatwedo/programmes/vre2.aspx (accessed 31 January, 2009), is broadly analogous with the ACLS report:

> [. . .] a framework of resources to support the underlying processes of research on both small and large scales, particularly for those disciplines which are not well catered for by the current infrastructure.

However, there are two especially important elements that pertain to both definitions: The term research in VRE ties it to a particular class of usage of e-Infrastructure, and the attendant intangibles referred to above. Second, the two VRE programmes which JISC have supported since 2004, by their very existence, underline the fact that VREs are typically project driven and designed strategically rather than responsively or incrementally.

The emphasis in the JISC definition on "disciplines that are not well catered for" begs crucial usability questions. The physical, and otherwise "hard" sciences have been dealing with the so-called data deluge for ten years or more (Hey and Trefethen, 2005, p. 817) and, as is well documented, this led to the development of the UK e-Science Core Programme (for more details see www.rcuk.ac.uk/escience/default.htm, accessed 30 January, 2009). However, the epistemic nature of research practices in the sciences is very different to those of the humanities and arts. Services to support the use of large-scale scientific instruments, and to distribute the resulting data to research teams throughout the world, tend to rely on definable and replicable workflows, which can be supported by software applications such as Taverna. The JISC VRE project MyExperiment (see www.myexperiment.org/, accessed 19 February, 2009) has proved highly successful for exactly this reason: as the project's investigators have written, "[w]orkflows are scientific objects in their own right" (Goble and De Roure, 2007, p. 1). Applications which demonstrate the ability of Grid-based Virtual Organizations (VOs) to orchestrate everyday digital services such as news feeds, TV clips and event ticket purchasing transactions, only serve to highlight that the design of such systems, and the technology behind them rely on their usage and components following established modes and patterns. In a paper describing the CONOISE and CONOISE-G projects for supporting VOs, Shao *et al.* (2004, p. 7) assume the presence of a "coherent VO management system" within which their model can select and deliver pre-defined services. Furthermore, as Fraser (2005, p. 8) has pointed out, the development of VREs and e-science are intrinsically linked.

However, research practices and data in the arts and humanities are frequently fuzzy, incomplete, dispersed, disputed or any combination of these. In the past decade or so – roughly the period since the inception of the e-science core programme – researchers in the arts and humanities disciplines have been producing more and more digital information. Driven by increased availability of relatively cheap digitization technologies and the development of software tools that support both existing research tasks and wholly new ones, the digital arts and humanities are now facing what might be termed a complexity deluge. This can be defined as the presence of a range of opportunities arising from the rate of technological change and the availability of e-infrastructure, that the mainstream academic community is not yet equipped to address its research questions with. For example, a PhD student with a background in museum and gallery studies might wish to study and visualize the use of space in exhibitions, but might not be aware of the existence of spatio-temporal visualization technologies which could throw new light on her material. Or a research team concerned with ancient documents that exist in fragmentary form in different museums and libraries around the world now have opportunities to use imaging and collaboration software that they might not be aware of. The obvious risk arising from this is that the VRE development agenda will be driven by the technology, and not the research questions.

The first part of this paper will review the still-emerging VRE concept in the light of the experiences of the arts and humanities, especially the AHRC-JISC-EPSRC Arts and Humanities E-Science Initiative (see www.ahessc.ac.uk/about, accessed 31 January 2009). Against this background, the second part will focus more specifically on the research agenda produced by the application of VRE tools and methods in the archaeology community. Archaeology forms a good case study, because its practice is distributed across the field, the classroom, the laboratory and the library; and the need to support post-excavation analysis and interpretation are broadly applicable to rest of the humanities. The conclusion will make some broad observations about the application of VREs within humanistic and artistic research practice, and seek to establish a set of principles of what the arts and humanities require, in order to be considered "well catered for" by VREs.

2. Levels of complexity: VREs in the arts and humanities

It is useful to reflect first on what a VRE is not. Google Earth, for example, is an online environment, which has extensive potential applications in the humanities and social sciences (e.g. Ullmann and Gorokhovich, 2006). It provides a support for certain research tasks within these disciplines by allowing undocumented users access to satellite imagery. The images can be studied and cached locally via Google's tiling mechanism, which also allows the selection and transfer of small amounts of data from vast repositories, along normal internet pipes. The researcher can use them as backdrops, or, annotate, and zoom to a variety of different scales.

Toponyms in Google Earth can be searched and retrieved, and the user can easily "bookmark" particular points using the "placemark" facility. Archaeologists wishing to carry out regional surveys – or even intra-site analysis, where the resolution of the imagery is high enough - can use it either as a backdrop for georeferenced information which they already have, or for illustrative purposes, within Google's intellectual property and copyright constraints. Furthermore, it has an unquestionable democratizing element, making available mapping and geovisualiztion technologies to humanists who might otherwise lack the skills or training to use specialized Geographic Information Systems (GIS) or archaeological illustration. Likewise for historians, it provides the capacity to produce online, and use locally, relatively high-quality (and aesthetically satisfying) cartographic illustrations. The potential value for the social sciences, especially with regard to combining geographic and non-geographic data, have been attested elsewhere (Goodchild, 2008, pp. 22-3). The data standard employed by Google Earth and Google Maps, as well as other online mapping platforms, is Keyhole Markup Language (KML). This XML-based script allows the easy and consistent encoding of coordinate, toponym and attribute data from multiple (and potentially unlimited) sources, and its transfer across platforms. In this sense, it meets a basic requirement for use within a VRE, using recognized and reusable standards for data encoding and transfer (KML has been recognized as an open standard by the international and interprofessional Open Geospatial Consortium – see www.opengeospatial.org, accessed 31 January 2009). There are technical drawbacks. The quality and resolution of the imagery is variable, so the capacity for the kind of research which can be carried out is, to an extent, limited by the project's geographical scope: some parts of the world have excellent resolution in Google Earth, others are covered at a much lower level.

In broad terms, Google Earth should not be considered a VRE for three reasons. First, there is no mechanism for managing or authenticating users, and therefore no facility for a user to record the means by which they can record and publish the methodology employed to reach any particular conclusion or visualization. Second, although the user can create and store their own data in the Google Earth environment, that data is "in the cloud", and the user therefore does not have ultimate control over how, or even if, it is preserved, accessed and stored. It is not, therefore, "their" data in any robust sense. And finally, the scope of potential uses is just too broad. Although collaboration on specific areas by individuals is possible, Google Earth contains a mass of conflicting priorities and interests. Any definition of research as the class of usage that defines a VRE (see section 1) requires all three components – the recording process, clear ownership (in every sense) of the data, and a focus on a particular question or topic – to be formally articulated and documented, in order to meet the standards of peer-review, research quality assessment, and funding success, that non-digital research is subject to.

What Google Earth can be regarded as is a component of a VRE. A perfect illustration of this is the Pleiades project, a collaborative web-based effort to collect, curate and disseminate information about places in Greco-Roman antiquity (see http://pleiades.stoa.org/, accessed 31 January 2009). An XML-based repository of information about place name, archaeological attributes, finds etc is maintained, and any user may propose additions or modifications, subject to a light-touch peer-review process. This project certainly meets every definition of a VRE – it has a definable presence, it allows only authenticated users to contribute to its knowledge base, and there is a quantifiable and coherent research purpose. Its use of the KML standard, and embedding of Google Maps in its web interface illustrates perfectly the distinction that should be drawn between a VRE and an open internet platform. The latter can be used within a VRE, but it is not one by itself. This distinction is particularly important in the arts and humanities where, as noted above (section 1), research processes are typically fuzzier and less definable than in the physical sciences.

The UK's Arts and Humanities E-Science Initiative has encouraged new thinking about the way in which researchers in these disciplines can collaborate digitally, and provides new opportunities to (re)consider the functionality of VREs. One example of this is the e-Dance project, which is led by the University of Bedford, with collaborators at the Open University and University of Manchester (Bailey *et al.*, 2008, p. 9). This project's research topic is performative practice in collaborative digital environments. Performative practice is inherently collaborative: if a particular choreography is designed for n actors, then each actor has a relationship with the others that is simultaneously guided and responsive. If a practice-led researcher wishes to reconstruct and study the composition of a piece, then they will need to be able to understand and map the movements of each of the actors who perform it. Usually, they will be reliant on standard dance notation, or perhaps still images or 2-D video of the piece being performed, but these do not provide detailed or exhaustive information about the mode and method of the dance. The e-dance project is therefore using motion capture hardware to create 3-D "motion sculptures", which "re-embody" the movements by representing them as 3-D pathways (Bailey *et al.*, 2008, pp. 13-14). This extremely advanced digitization process facilitates collaborative research. Crucially for the present discussion, the project is utilizing the MEMETIC tool, which was developed under JISC's VRE phase 1 programme to provide a mechanism for documenting the decision-making process during meetings (see www.memetic-vre.net/, accessed 31 January 2009). In the e-Dance project however, it is using the same concept and methodology to document the creative process. As with the Google Earth example earlier in this section, the choreographic motion capture technology does not, by itself, constitute a VRE application. But when it is combined with a collaborative technology such as MEMETIC, it meets every criterion which the literature ascribes to a VRE, and makes the point that a VRE can be about understanding data, as well as "just" sharing it with one's colleagues.

3. VREs in archaeology

Supporting the epistemic practice of archaeology, and the interpretation of archaeological data, presents particular challenges, and particular opportunities, for the VRE agenda. The process of conducting archaeological research has been very extensively written about, and a full theoretical history is beyond the scope of this paper (for an overview, see Renfrew and Bahn, 1991, pp. 17-40). However, the research cycle leading from the discovery and excavation of archaeological material in the field to its publication contains a number of discrete elements, which can be roughly generalized as follows:

- *Discovery*. An artefact is recovered from the field, either through survey or excavation.
- *Identification and attribution*. One or more attributes, including (but not necessarily exhaustively) object class, type, colour, dimensions and a provisional date are assigned to the artefact, based on its physical characteristics.

- *Cross-referencing.* The artefact is compared, whether using some formal measure such as dimensions or colour; or interpretively, where the researcher attributes it to a particular group or typology, with artefacts of similar type.
- *Interpretation.* The artefact's place in the wider regional and spatial context is determined.
- *Publication.* Representations and/or textual descriptions of the artefact are published either electronically or on paper. The artefact itself may enter a museum collection or other archive, where it will be given a non-random place within a context of other artefacts sharing its attributes.

Because archaeological fieldwork is by definition regional or site-specific, excavation directors generally focus the majority of their efforts at any one time on relatively small-scale data gathering activities. This produces bodies of data that might be conceptually comparable, but are not standardized or consistent. For example, two separate excavation projects in different parts of the UK might recover examples of Samian pottery ware, but the sherds or vessels might be recorded and described in completely different ways, and at differing levels of detail. Furthermore, much archaeology in the UK and elsewhere is conducted in order to fulfill the legal obligations of land developers, which limits the time, human and financial resources available for excavation; and most organizations which carry out such "rescue" excavations – university archaeological service units, local authorities, private consultancies – have their own recording systems and procedures. It follows that there are still fewer resources available for the effective preservation and curation of complex information arising from such excavations. This occurs in the form of plans, finds data, GIS files and so on. Processing, managing and disseminating such data is therefore very problematic. To this must be added the fact that excavation is carried out by a range of public, academic and private bodies, which means that the data itself is likely to be stored in different systems and archives.

Despite – or perhaps because of – these factors, archaeology has been remarkably successful in developing e-research infrastructure above the project level. In a report on "E-science in archaeology" in 2006, Kilbride noted that:

> Over and above collaboration on specific research projects, it is arguable that archaeology is closer than almost any other discipline to transforming itself into a virtual research organization in which the different agents within the disciplinary body act as persistent consumers and producers of information through a continuous collaborative cycle of analysis and interpretation (Kilbride, 2006, p. 3).

The UK's Archaeology Data Service (see http://ads.ahds.ac.uk, accessed 31 January, 2009) is a national repository of archaeological data, providing access to datasets, reports and resources. As such it provides metadata, standards and support for those wishing to deposit datasets. One factor which arguably complicates such an approach from a research point-of-view, is the institutional model. The ADS is based hosted by the University of York, and is dependent on central funding for its core activities: this renders any sustainability model subject to such considerations. Given the project-driven nature of the UK's VRE agenda (see section 1), any VRE for archaeology is likely to face similar issues.

In the discussion of VREs, and models of data curation and distribution which are based on central and/or institutional storage and dissemination of data, it is easy to forget the interpretive implications of handling archaeological information digitally. As was seen in the previous section, this is also pertains to the broader arts and humanities VRE agenda. The act of publishing a database of archaeological information implicitly disguises the fact that creating the database in the first place is an interpretive process. In a paper published in 1997, which thus predated ubiquitous network computing, Hodder (1997) noted in a paragraph worth quoting at some length, that:

> The key point is that excavation method, data collection and data recording all depend on interpretation. Interpretation occurs at the trowel's edge. And yet, perhaps because of the technologies available to deal with very large sets of data, we have as archaeologists separated excavation methods out and seen them as prior to interpretation. Modern data-management systems perhaps allow some resolution of the contradiction. At any rate, it is time it was faced and dealt with (Hodder, 1997, p. 693).

Modern data-management systems have indeed been bought to bear on the issue of leveraging more value from online archaeological data. The Online Access to the Index of Archaeological Investigations (OASIS) project, for example, allows field excavators to enter details of their research data via an online web form; which greatly simplifies and streamlines the data entry aspect. However, it does not deal with the question of how data in the system itself should be approached from an interpretive perspective. That is, how can an online database be used to enhance and contribute to our knowledge about the past? One answer to this is the ability of such systems (including VREs) to support the integration of archaeological data. A recent US study found that:

> [. . .] because of the complexity of archaeological data, it is virtually impossible for allied scientists to rely on primary data; they must depend on syntheses of archaeologists' conclusions that are themselves several steps removed from primary data (Kintigh, 2006, p. 571).

At a more fundamental level, however, the creation of syntheses of this kind, and the semantic constructions involved in so doing, could also be described as "interpretation". The nexus between data gathering (or digitization) and interpretation is the crucial issue that librarians and technical developers are faced with when planning, or otherwise engaging with, the deployment of a VRE in archaeology, or indeed in the humanities more generally.

4. The Silchester VRE project

One project that illustrates these pitfalls excellently is the Silchester excavation in Hampshire, one of the largest urban Roman excavations in the UK. The site is unique for many reasons, but among its distinctions is that, unlike many other large Roman conurbations, such as Colchester or London, it experienced a total abandonment. The subsequent lack of development and good preservation conditions ensure its richness as an archaeological site (Stewart *et al.*, 2004, p. 222). It was first excavated in the Victorian period, and modern research began in 1997, conducted by the University of Reading's Department of Archaeology. The principle data repository for the excavation is the Integrated Archaeological Database (IADB), which is administered by the York Archaeological Trust (see www.iadb.co.uk/, accessed 31 January 2009).

The purpose of this electronic resource is to store, and make available for Silchester's community of archaeologists and subject experts in, for example, numismatics, environmental archaeology, ceramics etc., the data recorded by the field excavators in the course of each annual six-week field season.

In 2004, JISC funded the Silchester Roman Town: A Virtual Research Environment for Archaeology project (see www.jisc.ac.uk/whatwedo/programmes/vre1/silchester.aspx, accessed 31 January, 2009). This sought to address a number of the issues discussed above (see section 2), by linking the IADB more closely and intuitively with the data gathering process in the field, and with the subject experts. The project received funding under the second phase of JISC's VRE programme in 2007, as the Virtual Environment for Research in Archaeology (Baker *et al.*, 2008 – for a full list of publications relating to VERA see http://vera.rdg.ac.uk/publications.php, accessed 31 January 2009). Silchester has become a well-known example of the archaeological research cycle in action in a digital sense. It deals with the full range of types of archaeological evidence: numismatics, architecture, ceramics, paleoenvironment, spatial etc. The data are large and complex, the human expertise needed for its analysis and interpretation is geographically dispersed, and the experts themselves are unable to meet regularly at the site, or to discuss the finds either in situ or in their physical presence. The project therefore established the VRE to:

- enable digitization of material onsite and its direct uploading to the IADB; and
- provide experts with real-time access to the entire IADB.

The VRE has altered the onsite data collection process in a number of ways. As at most major excavations, the principle of data recording is based on the notion of the "context". A context may be described as the material record of a single occupation event, for example the deposition of soil in a hole or depression. Identifying a context requires expertise and training, as does recording it. When a context is identified by a fieldworker, a serial number is assigned from a master list. Details of the context's description, provenance, position in the site's stratigraphy, dimensions etc are recorded on a pro-forma "context card". Transferring this information to the IADB is a time-consuming and laborious digitization process. The VRE however connects the site directly with the IADB over the internet, using a broadband wireless aerial with a standard 1 mb downlink and 256 kb uplink at the site. The aerial itself is mounted on a barn 600 metres to the south of the excavation area (this in itself is a significant and successful test of wireless broadband technology in robust, outdoor environments: VREs requiring wireless technology are not limited to the laboratory, classroom or office). The IADB itself provides an interface containing the context records, images and site plans, which are related together using the archaeological convention of the Harris Matrix. The information from each context card is recorded in the matrix tree and is hyperlinked to the full record, with further hyperlinks embedded in the records themselves. The main technical problem with the IADB – which the project was tasked to address – was the server interoperability. Each server operates behind a proxy or firewall, and this was addressed by employing clients using JavaScript to issue queries to each server, and then amalgamate the results.

The VRE's original field strategy was for fieldworkers to use PDAs and a ruggedized laptop to collect data on finds and other features, and upload it directly to the database. When applied, however, the research team found this had significant drawbacks. In the area of small finds, for example, there were quality control problems, caused by incorrect or misidentified information being uploaded into the IADB (Baker *et al.*, 2008). The context card digitization process, although very time consuming, nonetheless formed a *de facto* quality control process. Especially at its early stages, the data gathering process is extremely informal: context cards are frequently completed over a period of time and in a non linear fashion; measurements are recoded in a variety of places and in a variety of ways; each excavator develops their own, idiosyncratic workflow system. A key role of the supervisor and database manager in such a system is to prepare the data by manually and visually identifying the inconsistencies, likely errors, misspellings, misidentifications, and so on that such a process inevitably produces. However, when fieldworkers were uploading information directly to the IADB, this informal quality control layer no longer applied. As a result, a large number of data objects that proved unsatisfactory for a variety of reasons were added to the IADB. In the second field season in which the VRE was deployed, the paper recording system was reintroduced, with the small finds supervisor collating the reports and uploading them herself. This revised data collection model, with the existing human management process operating alongside the VRE's broadband capability, worked extremely well, as the small finds manager herself has attested to the author. A major finding of the project's second phase is that digital pens, which digitize the fieldworker's handwriting as they write, and digital paper work far better than PDAs, since the former replicate the existing system without imposing cumbersome and unfamiliar hardware tools on the user.

Silchester provides an example of how the steps in the archaeological research cycle, from attribution through to interpretation can be reproduced and (arguably) their efficiency improved and capacity expanded within a VRE. The problems at the attribution stage itself – i.e. uploading accurate information about artefacts to the database – are essentially human ones. A discussion of human-computer interaction is beyond the scope of this paper, but it seems logical to suppose that with increased familiarity and training, most fieldworkers would be able to upload attribution data quickly and accurately. However, as the first phase of the Silchester VRE project draws to a close, it is clear that a formal and automated documentation system to keep track of field uploads is needed, to give site managers a trusted overview of all the workflows. This highlights the key distinction to be made between a VRE in the humanities and a VRE in the data-rich sciences: As in the MyExperiment example (see section 1), the workflows are already there, they are definable and defined, they can be easily articulated and documented. They therefore transfer very easily to the digital sphere. Archaeological workflows on the other hand are idiosyncratic, partly informal, and extremely difficult to define. They do not easily transfer to the digital sphere, without imposing the kind of *a priori* interpretive judgment on the evidence that Hodder warns against. It is difficult to envisage any professional archaeologist countenancing such a system.

A further critical issue is publications arising from VRE activity. In the past, research has been published in the form of articles, books, excavation reports and so on. Even the more modest "data deluge" experienced by the arts and humanities however has had a clear impact on these modes of publication: the UK Archaeology Data Service for example is now the custodian of over one million indexed online records (see http://ads.ahds.ac.uk/project/archaeotools/, accessed 19 February 2009) This exponentially increased level of access to data has little academic meaning if modes of publication cannot accommodate it. Organizing and managing such data to make them available to scholars, whilst preserving copyright and intellectual property at every stage of the research cycle is a key, and complex, challenge. One aspect of the Silchester project was the production of an article for the UK online journal *Internet Archaeology*, prepared in collaboration with the AHRC-funded "Linking e-archives with publications" project (LEAP) (Clarke *et al.*, 2007; for further details on LEAP see http://ads.ahds.ac.uk/catalogue/archive/silchester_ahrc_2007/index.cfm?CFID = 2251847&CFTOKEN = 26966213, accessed 31 January 2009). Where a discussion in a published article focuses on a particular set of primary data, there is a clear logic to deploying VRE tools, where available, to make that data available alongside the discussion. However, in such situations it is incumbent upon the VRE to ensure that those data are trustworthy, or, if they are not (or might not be), to provide transparent documentation about the process(es) of analysis and manipulation via which they have come to support the published discussion. Some users, and some providers of data, might have (very understandable) concerns about making that data available. Recalling the Google Earth example (see section 2), the term "research" in Virtual Research Environment implies that the outputs meet "conventional" standards of peer review and evaluation.

5. Conclusion

As Fraser (2005, p. 1) correctly states, "VREs within and beyond institutional environments are dependent on core e-infrastructure". It is probably accurate to say that there is a consensus in the VRE developer community, and in the limited sections of the academic world currently engaged with VREs, that a VRE may be described as a component of e-Infrastructure that is configured around research needs. In this sense it differs from a conventional research environment, which is likely to be configured around institutional and discipline-specific frameworks. It is almost paradoxical, therefore, that the success of scientific VRE projects such as MyExperiment are, to a great extent, contingent on the stable nature of scientific workflows and data.

The successful development and deployment of a VRE in the humanities or arts is contingent on recognizing that workflows are not scientific objects in their own right. Workflows in these disciplines are highly individual, often informal, and cannot be easily shared or reproduced. The focus of VREs in the arts and humanities should therefore be on supporting existing research practice, rather than seeking to revolutionize it. Any project plan for such a VRE should divide the research (or teaching) practice it proposes to support into three categories:

(1) New processes it seeks to introduce to the practice. This could include, for example, replacing or supplementing email communication with Access Grid, or some other collaborative chat facility.

(2) Processes it seeks to digitize (or replicate digitally). This could include, for example, replacing "ordinary" context cards at Silchester with digital pens and paper.

(3) Processes it does not seek to affect (or at least affect directly). If users – especially users unfamiliar with digital technologies - are to trust VREs, then it is just as important to define explicitly what a VRE cannot (and should not) try to do, as to what it can.

The examples given here demonstrate some successful outcomes of VRE and related activities that have been driven by strategic funding. As with the UK's e-Science programme itself, the challenge now is to establish such activities in everyday research practice, across all the disciplines that can draw benefit from them.

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