ENHANCING THE UNDERSTANDING OF STATISTICAL DATA THROUGH THE CREATION OF PHYSICAL OBJECTS

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Abstract: For many people outside of the scientific community statistical information and graphics remain abstract and unintelligible. This research begins to investigate how we might interrogate statistical information from the engineering sector through the creation of material/physical objects, with the intention of bringing better understanding and increased accessibility to scientific data.
This inquiry will be achieved through a strategy of media transformations that move information sources between digital and material environments, for example; by translating digital statistics into 3D computer models, which can then be output into real-world objects using 3D printing techniques. Undertaken by a multidisciplinary team of designers, engineers, technologists and end-user communities the project aims to investigate how these translation strategies can be used to communicate and transfer knowledge between different stakeholders. User centered activities will be conducted to explore what visual metaphors might be appropriate for different contexts.

Keywords: *Information Visualisation, Tangible Data, Creative Practice*

1. Introduction

In the last few years we have seen a marked increase in interest into how we can build stronger relationships between digital and physical environments. The recent exhibition at the V&A, the "Power of Making" (Power of Making, 2011) exemplifies this interest in exploring ways in which we can creatively combine the tangible qualities of material culture with the dynamic attributes of the digital. This proposal is based on theoretical writings and research by the author around the concept of the 'data-object' (Gwilt 2011), and other emergent work in the area (Klanten 2010). The intention of the proposed research is to apply the concept of the data-object to a set of practice-based design activities, which explore how our understanding of statistical/scientific data is mediated when it is represented as a physical object.
The data driven object as a communication device needs to be considered in light of the existing conversations taking place in the area of information visualisation. This includes issues around complexity of information, the veracity of the visualisations, user engagement, knowledge transfer and so on (Tufte 1993; Ware 2004). However, the creation of a physical object based on a digital data

set is in a sense a new 'complex' media form which has the potential to speak to the inherit traits found in both digital and material cultures. Part of this research will include an investigation into how, or indeed if, these data-objects can successfully combine properties from both digital and material paradigms in the communicate their message. Properties that on the one hand include digital notions such as morphology, data density and networkability, which potentially give widespread and democratic access to information and experience (something that is often difficult to achieve with a physical object). And on the other hand physical objects, which often hold strong and inherent cultural notions of authenticity and value, ascribed through the empiric experience and interaction with a singular physical object (Riggins 1994). In the best case scenario the manifestation of digital information into a material form should utilise the strengths of both of these two paradigms. Moreover, these synthesized constructs offer up a new way of looking at the digital/material relationship. The data-object might be considered a syncretic agent, capable of appealing to a cross-section of communities.

Two examples of work in this emergent field are the data driven sculptures of Abigail Reynolds and Mitchell Whitelaw. In Abigail Reynolds work *Mount Fear* (2002) sheets of laser-cut corrugated cardboard are cut out and stuck together to create a room sized three-dimensional bar chart of crime statistics in London. In this work audience members can walk around the data-based sculpture where, thorough the use of scale and materials, the roughly constructed object creates an intimidating representation of the data content. In another example the work entitled *Measuring Cup (Sydney 1859-2009)* (2010) by Mitchell Whitelaw, uses temperature statistics from Sydney, Australia to inform the shape and form of a plastic tumbler. The tumbler is constructed in a series of rings, with each ring representing one year of statistics. The rings of data build up the sides of the container, and like the growth rings of a tree, the rings of annual temperature data create a tangible realisation of growth and flux. In this physical representation of data the recent upward trend in overall temperatures combines to give the tumbler a flare upper lip that echoes the ergonomic convention typically used in the design of drinks containers.

Currently there is little formal research that examines the communicative potential of these types of creative works and this project hopes to add new knowledge to the field of creative information visualisation and design. For the purposes of this particular piece of research, data gathered on the 'openability' of consumer packaging was used to test the general concept of the data-object. This issue of packaging openability has been identified as an area of major concern for an aging community, which needs to be addressed by packaging design engineers. Specifically the project utilises data collected by the Engineered Packaging Research Group and Departments of Mechanical Engineering, and Engineering Materials at the University of Sheffield. In research led by Dr Alaster Yoxall, a Principal Research Fellow in Human Centered Engineering at Sheffield Hallam University (SHU), the findings of a simple scientific grip test suggested that the problem of difficult-to-open packaging is especially apparent when looking at elderly people or people with a disability (Yoxall 2006). As this research highlighted, ageing brings with it many issues, not least a loss of strength and dexterity, and in order to design effective packaging an understanding of the ability of aged consumers to effectively use established forms of packaging such as glass jars and bottles is becoming increasing important.

After meetings with Dr Yoxall and other engineers/researchers responsible for gathering the initial data, it was identified that a significant problem existed in sharing this information with specific parties outside of the engineering field. In particular the question of how to communicate these findings effectively to designers, who in the experience of the engineers involved in collecting the data did not typically respond well to statistical information presented in the form of a graph was noted. Developing strategies for communicating the relationship between age and dexterity/strength and the importance of understanding this relationship, for different sectors of the community (including designers) was therefore acknowledged as being an important research question worthy of investigation. Further meetings with Professor Pat Langdon, a senior researcher in the Engineering Design Centre at Cambridge University affirmed the importance of this issue. Through these meetings the need to develop design tools and creative approaches in addressing the problem was also recognised (Langdon et al. 2007). In addition it was acknowledged that different sectors of the community including designers, carers, the general public might have a specific requirement of the

data or need a particular level of insight into the problem, and that this range of requirements might be addressed through the development/use of a variety of information forms. The skill sets and resources of the Art and Design Research Centre, in the Faculty of Arts, Computing, Engineering and Sciences at Sheffield Hallam University were identified as being of a relevant mix of disciplines to address this problem. In particular a strong relationship and history of interdisciplinary research projects occurring between creative practices, design and engineering within the research institution, and a close link to the resources, staff and students in the Sheffield Institute of Arts was identified as being a healthy environment from which to undertake the research.

2. Aims and Objectives

The intention of this research was to run a practice-based scoping project that would explore the cross-sector communicative potentials of creating data-informed objects. Seed funding to run the initial stage of the research was successfully gained from the Arts and Humanities Research Council (AHRC), Digital Transformations initiative (Digital Transformations initiative, 2011). Initially we intended to conduct user-centred focus groups/interviews with designers and other stakeholders that would A; introduce the scientific data and findings outlined above and B; introduce the notion of the data-object as a device for communicating this information. The findings of these focus groups were then to be used to inform the creation of a second round of data-object prototypes. An initial selection of data-objects was introduced to the focus groups to examine whether the attendant qualities of the media form could reveal different insights and comprehension of the data beyond the conventional engineering paradigm. By the end of the project, it is hoped that we will be able to comment on how different stakeholders might read these data-objects in comparison to the usual data presentation strategies, and to draw some conclusions as to the potential benefits of representing data in these new forms. The process and outcomes of the scoping exercise will also be documented in a website and through a public exhibition (Data Objects, 2011). The findings will also form the basis for additional research into the use of data-objects (based on larger more complex data sets) to enhance knowledge and understanding across a variety of communities.

2.1. Pilot Study

Three data-object design concepts have been developed which were used to test the concept with a section of user communities. The activity of making these objects has been carefully documented and will in itself form part of the research evaluation methodology. Initial examples of data-objects were presented to a selection of adult participants from three stakeholder communities; engineers/scientists, designers and the general public (with a non-scientific/engineering or design background). Semi-structured interviews with individual representatives from each community were undertaken to explore the following research questions:

- Can the creation of physical artefacts based on data extracted from statistical digital information systems change the way we read, interpret and respond to digital information?
- By translating information from the digital environment into a physical environment what new understanding (if any) to the original information is engendered?
- What role do the material qualities of the objects play in comprehending data when moving from digital to material environments?

Details on how we carried out this user testing are described in section 3 below.

2.2. Creating the Objects

As part of a practice-based methodology the statistical data was initially interpreted by Dr Koutaro Sano, a Japanese ceramicist, designer, and researcher. These interpretations were undertaken after briefings from Dr Alaster Yoxall, on the meaning of the original scientific data, and briefings from Professor Ian Gwilt on the background concept of the data-object. Dr Sano was then encouraged to explore a number of creative interpretations of the data. During the concept development stage a discussion was had about what different types of visual metaphors and ways of representing the statistical data in the form of a physical object might be used. Whether or not it was necessary to relate concepts to the context of the origin dataset was also discussed. It was proposed that three separate

concepts be developed to the test the hypothesis of the data-object. One concept used the metaphor of landscape, another was based on a series of jar lids, which had a close symbolic relationship to the original data, and a third concept based on an abstract form were chosen. Working with the other project members, Dr Sano began by developing some initial ideas. First, these ideas were progressed through conversation, and recorded in the form of note taking and sketches (Fig 1.). Second, initial sketches were then developed to inform the construction of three-dimensional 'test' models (Fig 2.). Third, more robust and developed models were made that could be used in the focus group activities. For this stage a number of fabrication techniques were trialled (Figs 3. and 4.). The design workshop facilities and technical staff at Sheffield Hallam University were engaged to help make models using traditional materials including, clay, wax, and plaster. At the same time digital fabrication techniques in the shape of Fuse Deposition Rapid Prototyping were used to make robust objects. A selection of differently fabricated objects were then chosen to present to the user communities.

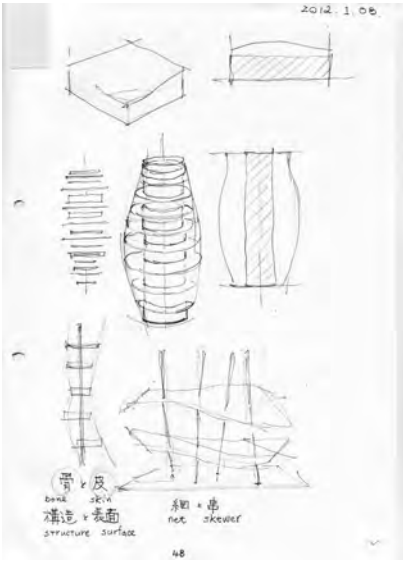

Figure 1. Initial drawing ideas.

Figure 2. Test models showing 3 initial concepts.

Figure 3. Developed model – Landscape concept in clay.

Figure 4. Developed model – Jar lid concept, Rapid Prototype model.

3. Testing the Premise

Using the three data-object concepts developed by the research team through the design process outlined above, the research set out to investigate if the translation of statistical information into physical artefacts could aid cognition and understanding of complex digital data. Using semi-structured questions, interviews were undertaken with representatives from three user communities; designers, scientists/engineers and the general public. The interviews were used as a vehicle to explore, from a users perspective, whether or not, data-objects could be used to aid cognition of statistical/graph-based data and to question what insights/conversations into the meaning of the data represented in the data-object might be engendered. Interview questions were also used to examine what the effect/impact of the physical materials/affordances of the various data-objects, such as scale, material usage and finish might have on comprehension and engagement.

Interviews of 10 representatives for each user community were undertaken (30 in total). These were conducted in the Art and Design Research Centre (ADRC) at Sheffield Hallam University in individual sessions that lasted for a duration of between 15 - 20 minutes each. All sessions were conducted by the same two investigators and notes and photographs were taken during the sessions. Each session followed the same format, which is outlined as follows; after initial conversations around research ethics, process and compliance etc. the data-objects, which were arranged on a table in front of the participants were brought to their attention. The objects consisted of, small and large landscape representations of the data (made of plaster and Rapid Prototype plastic), two related objects which represented the data using the metaphor of a Jar lid, and another Rapid Prototype object which consisted of a number of circular discs mounted on concentric spokes radiating from the same hub (Fig 5.). Participants were invited to interacted with the data-objects which were described as containing/representing information, (the details of the specific information were not revealed at this point). The data-objects were examined in turn (in a random order) and questions as to the meaning/nature of the object and what information/data it might represent were asked. After two or three objects had been discussed, a graph of the original data was shown and explained, after which the remaining objects were examined and the initial objects were returned to.

Figure 5. Data-objects on table ready for user testing.

4. Initial Findings

Following the interviews some general trends in respect to the meaning/potential use of the data-object as a means of communicating statistical information began to appear. Similar patterns of response and observation emerged from each user community. From the scientific/engineering community the initial response to the data-objects was frequently one of bemusement, and comments along the lines of why not stick with the original graphical representation were recorded, for example one participant suggested "why not just use a pretty graph". However, on interacting with the objects – which usually entailed picking up the objects, turning them around, feeling the differences in weight, surface texture form etc. there were a number of comments made which referred to how the different objects gave different impressions of data density – this was most commonly related to the surface textures of the landscape based models. Indeed the tactile nature of the objects was generally seen across all three communities as something that might be useful in communicating data in this form. This idea of data density being analogous to the granularity of the objects surface was frequently commented on – both as a positive and a negative, in terms of comprehension.

In many cases after the original graph-based data was explained there was a positive shift towards the concept of the data-object, in particular the physical objects where often thought to be more likely to stimulate a discussion around the data and the implications of the data for individuals. After the revealing of the graphical data the potential value of the data-objects as a discursive form was frequently commented on, comments such as "graphs work for papers they don't work for people" and "objects are much more powerful as a communication tool" reflected this train of thought.

Patterns in the data-object preferences (landscape, jar lid, abstract shape) also began to emerge within the user communities. In general the scientist/engineers favoured the jar lid shaped objects that were perceived as having a close correlation to the graphical data in terms of how the data was presented, but few people made the connection between the data content and the metaphor of the jar lid. The smooth plastic Rapid Prototype was also preferred by this community as it was seen to be more comprehensible than the 'noisy' surfaces of the plaster landscape models. From the design community a number of comments were made about how they do not generally use graphs or statistical information, and did not readily respond to information in theses forms. However the plaster-based models were often seen to be engaging as "they invite you to explore possibilities that are more tangible and more satisfying", and "they are better than prescriptive forms as they make you want to decode the object". Another participant "really liked the interpretative nature of the large plaster object" and found it more engaging "not black and white" (Fig 6.).

Figure 6. User testing the data-objects.

If the general preferences for the scientific/engineering community were towards the analytical representation of data as shown in the graph and the jar lid data-object, and the preferences from the design-based participants were centered around the more open-ended, experiential data representations, predictably the participants drawn from the non-scientific, non-design community sat between these two camps. Some of these participants were used to looking at statistical/graph-based data as part of their work-based activity and preferred this approach while others – although not familiar with data presented in the form of an object, found the physical models to be "much more memorable". Interestingly when asked about how they might visualize the data a number of participants thought that colour would be a useful addition.

Across all the user communities the data-object based on the circular discs was seen to have a particular resonance with the original statistical information. Within this object each disc has a different resistance (when pushed), which correlates to strength/ability at different ages. This tangible feedback was seen to offer an analogues relationship to the data displayed in the graph and as such was easy to interpret and memorable due to the experience. However, there was some disagreement as to whether an easy to push disc represented an aged/weak person or a person who was young and strong. This point of contention highlighted a broader concern, relevant to all the data-objects tested, wherein it was commonly agreed that for the objects to have any use beyond the visual aesthetics and tactile experience of the form, some contextualization, in the shape of instructional information on how to read the object was required.

5. Future Directions

The pilot study described in the paper indicates that the premise of the data-object as a communication tool that can add insight and aid comprehension of technical/scientific data for a non-technical audience has some merit. However, it is apparent that the success of the visual language used within the data-object is dependent on context of use, particularly in terms of the users expectation/requirements from the data contained within the form. Whether or not the data-object needs to somehow embody the nature of the content within its form needs further investigation, but according to this preliminary study there is a relationship between comprehension and decisions made around fabrication techniques, finishes and physical form. More work on the use of metaphor, shape, and material usage, use of textures, colours, contextual graphics and so forth is required. It is also apparent that there is no single solution for creating successful data-objects, and it was never the suggestion of this research that one visual representational form should 'replace' another. What is becoming clearer is that the extended visual language of the data-object can not only work in tandem with more traditional data visualisation forms like statistical graphs, but can also offer a rich, dialogical bridge or media-bridge that can complement more analytical forms, and by doing so potentially broaden the community of understanding.

In terms of future directions additional research on the features outlined above is intended, and applying the concept of the data-object to other more complex data sources is seen as an avenue which will offer further potential for investigation. It is our intention to publish findings in appropriate professional and technical journals and to present this and future research on the area to a variety of audiences in the creative and cultural sectors, academic and engineering communities and to promote

knowledge transfer opportunities by expanding the methodology to other information sources and contexts.

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