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ARTICLE

Designing an Exploratory Visual Interface to the Results of Citizen Surveys

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Surveys are used by public authorities to monitor the quality and reach of public services and provide information needed to help improve them. The results of such surveys tend to be used in internal reports, with highly-aggregated summaries being released to the public. Even where data are released, many citizens do not have the capability to explore and interpret them. This offers limited scope for citizens to explore the results and use them to help hold service providers to account – objectives that are increasingly important in public service provision. We work closely with an English local authority to develop an innovative interactive interface to a citizen survey to demonstrate what can be achieved by applying a visual approach to the exploration of such data. In so doing we *(a)* make a case for web-based interactive visualisation to make this kind of information accessible both *internally* to those working in local government and *externally* to citizens in a way that is not achieved through a regular Open Data release or existing applications; *(b)* use techniques from both cartography and information visualization to inform the design of fluid visual interactions that enable diverse users – from the casual citizen browser to those interested in more in-depth analysis – to view, compare and interpret the survey outputs from a wide variety of perspectives; and *(c)* document experiences and reactions to the provision of information in this form, with log analysis playing a role in this exercise. Our reflections on our successes and otherwise will inform future exploratory interface design to help citizens access information and hold public service providers to account.

Keywords: Public, citizens, survey, design, data exploration, open data

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1. Introduction

Surveys of citizens' attitudes towards public services help organisations, political parties and government departments determine attitudes and levels of satisfaction. They are increasingly important in helping establish *how successfully* local services are delivered and whether they are delivered to publicly-acceptable standards in *all places* and to *all sections of society*. The results are used internally for auditing, planning and improvement purposes. They are regularly released for *external* use, usually as reports that give headline summaries based on data aggregates. These can hide or obscure local variations and differences in views from particular sections of society, including important minorities. This may make it difficult for the citizens who produced the data to relate their own circumstances and characteristics to the reports.

Leicestershire County Council (LCC) is a local authority – an elected administrative body, which, as one of 27 county councils in England, governs and provides local services. We worked with LCC, which represents a population of more than half a million in the county of Leicestershire, as part of a UK government initiative to "*establish new and untested approaches*" to making information accessible to citizens (CLG 2008). Our focus is the "Place Survey" – an exercise designed for the UK Government to assess local authority performance and to help local authorities improve services and policy. It was carried out by each English local authority in 2008 to "*capture local views, experiences and perceptions... to determine whether interventions made in an area result in the right outcomes for local people*" (CLG 2009a). In Leicestershire, 8,000 respondents gave their opinions on how well services were being run, what needed improving and whether they considered their area to be a good place to live (Figure 1). Like other local authorities, LCC use the results to support policy decisions and produced public reports of their findings (CLG 2009c,b). Although the results of the Place Survey were not originally primarily intended for public consumption, they have potential to help citizens hold governments to account.

Our aim is to open up these rich data to support analysts within the local authority as they inform policy and to make the data more accessible for citizen scrutiny. Visualization can be used successfully in local authorities to make sense of complex multifarious data in the contexts of analysis and policy (Slingsby *et al.* 2011). Providing information in ways that encourage citizen participation is considered a means by which public service providers may be held to account by the populations they serve. Using exploratory visualization in both contexts contributes to the Grand Challenge for information visualisation proposed by Munzner (2008): for "*total political transparency*" and "*to provide the capability for analysis [to be] equally distributed in society*".

Our solution[1] draws upon our design experience and the expertise of members of the Research & Insights Team at LCC. It incorporates good practice from data visualisation and interactive cartography in combining layout, representation, interaction and narrative in novel ways to deliver a new exploratory visual interface to citizen survey data. This visual application is designed to support a wide range of local authority staff and citizens in engaging with and learning about both the survey itself and the visual approaches used, by studying variation in attitudes, opinions and public service delivery across the county. It enables analysts to identify outliers and trends and citizens to relate their own situation to that of their wider community across a number of themes and over a range of scales. The methods used are transferable to other areas – the Place Survey

[1] `http://www.lsr-online.org/placesurvey.html`

Figure 1. Excerpts from the Place Survey questionnaire run by LCC.

being a national survey – and to other citizen surveys.

We describe the approach and the design decisions here and in doing so make a number of contributions: *(a)* a rationale for making public survey data accessible both *externally* to citizens and *internally* to those working in local government using interactive visualisation as an alternative to a straightforward Open Data release; *(b)*: design considerations for using interactive visualisation to achieve this; and *(c)*: experiences and reactions that may help others involved in similar work.

2. Open Data and Visual Data Exploration

A laudable way to help improve government transparency and accountability is through the release of Open Data (OKF 2012). The Open Data movement has strong political support and many governments encourage and legislate for departments and public agencies to release data through Open Data portals such as `data.gov`[1] and `data.gov.uk`[2]. This enables members of the public to use these and other data to scrutinise the performance of public agencies and help hold public service providers to account. For example, data-driven journalism (EJC 2010) is an increasingly important means of investigative reporting that draws heavily on such sources of Open Data. It uses static and interactive infographics to present data and link them to narratives in compelling and engaging ways.

It is also becoming easier for citizens as a whole to obtain and explore these data, with advances in web technology, the ubiquity of Internet-enabled computers and a plethora of free services and tools. Software vendors and diverse sections of the web community collate (e.g., The Guardian Data Store[3]), catalogue (e.g., `data.gov`[4]) and repackage data (e.g., TheyWorkForYou[5]) and use freely-accessible software (e.g., Google Public Data Explorer[6]) and platforms (e.g., ManyEyes[7], Viegas *et al.* 2007 and Tableau Public[8]) to visualize data. There are also free software libraries (e.g., D3[9], Bostock *et al.* 2011), dynamic scripting languages (e.g., JavaScript) and 'mashupable' tools (Miller 2006) that

[1] `http://www.data.gov`
[2] `http://www.data.gov.uk`
[3] `http://www.guardian.co.uk/data`
[4] `http://www.data.gov`
[5] `http://www.theyworkforyou.com`
[6] `https://www.google.co.uk/publicdata/`
[7] `http://www-958.ibm.com`
[8] `http://www.tableausoftware.com/public`
[9] `http://d3js.org`

make working with Open Data achievable for more people than ever before.

For these reasons, is it often assumed that if data are released, the 'community' will use them and thus government will become more accountable. However there are two reasons why this might not be the case. Firstly, Open Data are often released in aggregate form, resulting in similar restrictions to the headline summaries in reports. The reasons for this might be political (e.g., deliberately concealing detail within the data), technical (e.g., the disaggregated dataset may be too large to handle easily), legal (e.g., permission may not have been given by participants) and the need to maintain privacy. For example, the Place Survey data are not publicly available in disaggregated form because some individual records may contain information that may compromise some individuals' anonymity. Secondly, in spite of the relative ease with which people can process such data compared to a decade ago, the majority of citizens do not have the time to invest in data analysis, nor developing the technical skills required to do so. In many cases they can consume the data through web-based visual interfaces designed for public consumption, which include those that compare, for example, debt[1], lending[2], inequality[3], health[4] and income[5] as well as sites that collate visualization examples (e.g., Information Aesthetics[6]). However, these public-facing tools often sacrifice exploratory potential for ease of use and may not take advantage of some of the more recent developments in visualization. A notable exception is SENSE.US (Heer 2007), which offers excellent potential for exploration, targeting experienced social-media savvy web users and emphasising the collaborative annotation of a limited set of chart types rather than visualisation design decisions. The benefit of the design is the ability of many users to share their data insights. SENSE.US provides limited capability for juxtaposed visual comparison (Gleicher *et al.* 2011). As we shall see, rapidly comparing different facets of the data is important for both analysts and citizens in the Place Survey context.

Here we propose and demonstrate an *interactive visual alternative* to simply releasing disaggregated Place Survey data. In doing so we aim to address both the privacy concerns of releasing the necessary data to allow detailed exploration of geographical and attribute variation and make these data easily accessible and explorable to a range of citizens from the casual browser to the more advanced user – such as the analysts working in the Research & Insights Team at LCC. In addition we aim to demonstrate the kinds of analytical capability and personalisation that visualization offers to this broad audience when considering citizen surveys.

3. Design process

The novel exploratory visual interface to the Place Survey was developed iteratively and collaboratively using our expertise and that of our LCC colleagues. Initially, we established requirements through a one-day workshop involving seven LCC employees, including members of the Research & Insights Team. Each brought different expertise in terms of their roles and focii within the local authority, the community groups with whom they worked and in disseminating information to the public. We did not include a requirements gathering exercise from Leicestershire citizens directly, partly because of

[1]http://www.bbc.co.uk/news/business-13361930
[2]http://www.bbc.co.uk/news/business-15748696
[3]http://www.newyorker.com/sandbox/business/subway.html
[4]http://www.nepho.org.uk/atlas/euro-comparators/
[5]http://www.neighbourhood.statistics.gov.uk/HTMLDocs/incomeestimates.html
[6]http://infosthetics.com/

the nature of the exercise in which we were aiming to produce innovative and accessible exploratory interfaces and partly because of the high levels of public engagement experienced by our LCC colleagues.

The design and development work was carried out in two phases. Initial designs were generated via a parallel prototyping process (Dow *et al.* 2010) whereby individual researchers each devised a prototype independently. These prototypes were built as paper sketches before being shared amongst members of the design group. They were based on the established requirements and also a series of guidelines developed through post-workshop discussion amongst the design team (these are presented in section 3.2, below).

From these paper prototypes, an agreed set of ‘data sketches’ (Lloyd and Dykes 2011) were built. These combinations of functionality, data and interaction enable us to rapidly modify and develop interfaces to data and undertake ‘design experiments’ through which design ideas are explored in light of the data.

These were modified in two iterations as summarised in Table 2. Initially we prioritised functionality development in these digital prototypes to establish whether design ideas were successful in relation to requirements in the context of data. We then met with LCC at a second workshop to discuss how effective this functionality was from an analytic perspective, how usable it was by LCC staff and how well it met the wider project remit (in terms of novelty and potential for citizen engagement). In phase II, we did not add new functionality, but concentrated on developing the application for public release having received broadly positive feedback on existing functionality and design. Improvements to the fluidity and the incremental exposure of functionality were refined in this phase.

3.1. *Requirements Workshop*

The workshop followed the guidelines and procedures described by Dykes *et al.* (2010). This approach achieves consensus in determining the overarching purpose of the work by identifying and discussing existing solutions and establishing general and specific aspirations and requirements. During the exercises, responses were gathered from individuals and these were ranked by groups of participants following established protocols (Dykes *et al.* 2010, Koh *et al.* 2011, Slingsby and Dykes 2012). This resulted in a structured set of views that could be summarised and consulted during design either in raw form or at a more abstract, higher level. The high-level list of requirements is provided in Table 1.

3.1.1. Existing solutions

Initially LCC presented details of the Place Survey, its use in local government and expectations. We then established the state of the art in local authority visualization by examining various interactive web-based graphics for comparing local authorities by key measures. One such tool, InstantAtlas[1], compares local authority profiles by various demographic indicators. Aimed at analysts within local authorities, it allows quick comparison with impressive functionality and offers data downloads for local analysis. However, the complexity of the interface with an initial view that assumes an understanding of confidence intervals, filtering and selection and the reliance upon a detailed user guide were considered barriers to use for occasional and casual users. Some of the interactions and visuals mapped to citizen users, but the interface was deemed too heavy and complex. We aimed for more immediacy, flexibility and higher levels of fluid inter-

[1] `http://bit.ly/Hp0ch3`

action. LCC's web-based solution, LSR Online[2] provides aggregate results for the whole county and each of its seven districts. It allows question responses to be compared with those of other local authorities through maps and graphs. The graph sorting it employs is an effective way of presenting the distribution of scores, but the data are too aggregated to show detailed variation *within* local authorities and once again the interface is not designed with casual, non-analyst, users in mind.

We also examined commercial dashboard-style solutions, all of which offered a great deal of flexibility but were clearly designed for those with both data analytical skills and experience. While Andrienko *et al.* (2010) argue that "*everyone is a spatio-temporal analyst*" they highlight the need for suitable tools to allow the general public to exploit those skills without extensive prior training or software familiarity, and in particular for such tools to be accessible and adaptable to the kinds of "*personal analyses*" required by a general audience.

The existing public-facing examples we considered (now offline), while comparatively easy to operate, failed to follow established good practice in cartographic and data visualisation design. For example, EGov Toolkit's 'heatmaps' of Place Survey responses were inappropriately represented as a continuous phenomenon, even in areas where data were sparse. This contravenes cartographic good practice (MacEachren *et al.* 1994) and meant that the maps themselves were unhelpfully dominated by interpolation artefacts. These examples also lacked the levels of interaction and speed of response to which we aspired.

3.1.2. Scope and requirements

The project brief was to develop a pilot study to help "*establish new and untested approaches*" to making information accessible to citizens in the light of advances in data visualization and to "*push out the boat*" in terms of the approaches used in so-doing (CLG 2008). As the term 'citizens' refers to a large and diverse group of individuals in terms of access to web technology, technical ability and interest, it was important for our design to accommodate some of this diversity, supporting both the casual browser and the citizen with a more in-depth interest in the results, whilst employing novel approaches to information presentation and access. We established high-level requirements using a visualisation awareness session (Koh *et al.* 2011), followed by a combination of brainstorming and structured exercises as described by Dykes *et al.* (2010). These included a discussion and prioritisation of *needs*, forms of *innovation* that could be used and a post-workshop exercise in which LCC participants were asked to develop *user stories* based upon their areas of expertise, to enable us to ground the development of the application in valid use cases.

Characteristic needs included: *look beautiful, be intuitive and surprise people*; *be educational "by stealth"*; *make information accessible, engaging, useful and used*; *simplify the interrogation of what is a large and complex data set*. The *simplify* need is a complex one, particularly in light of the requirement to "*push out the boat*" and serve both casual and more advanced analysts. Some specific guidance was offered to address this issue however, indicating that the solution should: *start simple but allow more complex analysis over time*; *slowly draw the user from the simple to the unfamiliar / complex.*

Much of the visualization shown in our awareness workshop was deemed innovative by our local authority colleagues, but they were able to identify generic approaches that cut across these examples through which this criterion could be fulfilled. Examples include:

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[2] `http://bit.ly/HsSOzK`

Looking at the visualisation aspect rather than trying to focus on the actual piece of data or what's in it; *Allowing combination of data to create patterns that resonate in a useful way*; *Looking to put the citizen at the heart of the system rather than provider driven.* In light of the latter of these, we received guidance that postcodes should be used to help people find known localities and thus ensure that personal local information could be identified. These references are better known than the somewhat convoluted names of units in the hierarchical administrative geography, into which postcode zones do not always tesselate, and were deemed essential to enable citizens to position themselves in the data.

We collected a series of user stories shortly after the workshop. These involved alcohol awareness, library closure, anti-social behaviour, moving house, neighbourhood policing and youth services. Examples include citizens who...

- "*After reading ... about a change in opening hours of their local library ... uses the prototype to know what others think of the local issue in their immediate neighbourhood*";
- "*Looks up how the parish compares with the next door village on perceived anti-social behaviour... Realises that the problem is greater in their area than elsewhere. Can produce a powerful visualization of the data using different data sort options in order to make a powerful case that something needs to be done or of the impact on older people*";
- "*[is] looking to move house. ...They are interested in the perceptions of people with similar circumstances to them*"

This rich, structured source of information to inform designs was used in two ways. Firstly we generalised, developing: a generic scenario actor ('*citizen of Leicestershire*') and context-independent scenario description containing 12 outcomes; seven *key themes* – possible angles on the design; and a summary of the most important high level requirements. Secondly we made the original low level responses available to all those involved in design and development in an open document for continual consideration and inspiration. These sources were used continually to inform design discussion, planning and decisions. Specifically, we used the stories to ensure that our interactive interface supported the construction of these kinds of narratives.

The high level requirements and reasons for them are summarised in Table 1. 'Suitability for a wide range of users' (R5) acknowledges the wide diversity of users for which we are designing, reflecting the challenge of reconciling 'intuitive' (R3) and 'rich functionality' (R4). 'Rich functionality' (R4) follows from the specific project goal to "*push out the boat*" by trying new and untested approaches for providing access to timely and personalisable information. It also follows from the observation (section 3.1.1) that many public-facing systems have a simplified interface that offers simple glimpses into data that may not be adequate for local authority scrutiny. We needed to cater for a range of levels of engagement, in which various levels of relevant (R1) and informative (R2) knowledge could be obtained, in an intuitive (R3) interface that is aesthetically-pleasing (R6) and fun to use (R7). The latter requirement (R7) was important to LCC and the 'aesthetics' requirement (R6) follows from the observations that existing tools, such as those considered above, can often look intimidatingly technical, and evidence (both published and anecdotal) that aesthetics play important roles in engagement (Cawthon and Moere 2007, Elmqvist *et al.* 2011).

	Requirement	Description	Reason
R1	Relevant	Enable me identify responses from people who live near me or are like me.	Maintain interest
R2	Informative	Enable me to take knowledge away.	Allow citizen to hold provider to account.
R3	Intuitive	Easy to use without significant training.	Low barrier to use.
R4	Rich functionality	'Push the boat out' in terms of innovative functionality offered.	Expose citizens to richer analytical capability than usual.
R5	Suitable for range of users	Interests both the casual and experienced analyst.	Widen accessibility.
R6	Aesthetically-pleasing	Design that generates positive affect.	Invite interaction and exploration.
R7	Fun	Using the application does not feel like a chore.	Increase usage.

Table 1. Final set of requirements from the workshop.

3.2. *Design principles*

In light of the needs identified and the broader project remit we adopted and established principles for visual and interaction design to guide development.

3.2.1. Interaction design

The established needs made it clear that the existing interfaces were not sufficiently engaging, beautiful or simple. We sought to innovate by developing an engaging interface to geographic information with high levels of 'fluidity'. Developing ideas on information seeking that combine horizontal (more exploratory) and vertical (more focussed) activities (e.g., Dörk *et al.* 2011) along with the development team's own positive experiences of using information visualization in this context, were a key influence here. These are exemplified in Dörk *et al.* (2010) and Dörk *et al.* (2012). Elmqvist *et al.* (2011) consider fluid interfaces to be smooth, responsive, interactive and well-designed from the user's perspective. They hypothesise that these characteristics help make the use of exploratory interfaces that exhibit them efficient, illuminating and enjoyable. We considered this kind of fluid interaction to be important given R3, R6 and R7 and the citizen users being targeted. We aimed for greater fluidity than is typical in commercial GIS or the geographically focussed existing solutions that we had used. Elmqvist *et al.* (2011) propose design guidelines that help achieve this aim and informed the development of interactions in our design:

- *ID1: 'Use smooth animated transitions between states'* to help relate alternative, successive, graphical views (Bederson and Boltman 1999, Heer and Robertson 2007)
- *ID2: 'Provide immediate visual feedback on interaction'* in real-time
- *ID3: 'Use direct manipulation'* so that interaction operations are integrated in the visual representation.
- *ID4: 'Integrate user interface components in the visual representation'* (if ID3 is not possible) so that the interface is nearly invisible.
- *ID5: 'Reward interaction'* to encourage interaction with rewards such as animations, sounds, and pretty graphics.
- *ID6: 'Ensure that interaction never ends'* so there no 'dead ends' or 'irreversible operations'.
- *ID7: 'Reinforce a clear conceptual model'* with consistency of visual encoding, consistency of interaction and reversible actions.
- *ID8: Avoid explicit mode changes* to avoid drastic visual and interaction modality changes.

3.2.2. Visual design

Decisions on visual design were informed by established best practice in cartography and statistical graphics – essential in achieving R3 and R5. Positive feedback from both LCC and other users on a design style that we have developed also supported this need. The style involves structured layouts through which comparison can be undertaken and relationships identified at several hierarchical levels concurrently (Slingsby *et al.* 2009). It is space-filling and yet uncluttered and intended to enable us to achieve R1, R4 and R6, without compromising R3 or R5. Our visual design strategy is captured in five guidelines, that in a number of cases refer to more detailed guidelines and principles to be found in established texts and other literature:

- *VD1: 'Show the data'* – Tufte (1983) provides good guidance on emphasising the data and its relationships above other aspects of design in his *principles of graphical excellence* and ID3 and ID4 are approaches to interaction design that draw upon this principle.
- *VD2: 'Use ordered aligned bars as the primary means to show numeric information'* – we represent magnitudes with aligned bars where possible and use the order of these bars (the one aspect of Bertin's planar coordinates available once bars are aligned) to show other relationships. Where location is used to show spatial relationships we use area (of similarly shaped regular symbols) and colour to represent magnitudes. This approach is in line with the guidance of Cleveland and McGill (1984).
- *VD3: 'Use colour consistently to show variation in data'* – we use ColorBrewer guidance and schemes (Harrower and Brewer 2003) to represent data that vary in binary (for example when highlighting), diverging (when showing differences from a norm) and sequential (when showing a sequence of values) ways.
- *VD4: 'Use layout at multiple levels to relate data, through comparison, and perspectives'* – our designs use structured layout to support comparison through superposition and juxtaposition (Gleicher *et al.* 2011) and containment to emphasise membership and hierarchical structures
- *VD5: 'Use layout to represent multiple geographies'* – we use a variety of projections that contain varying amounts of positional geography in our designs and use interaction and animation for familiarisation and to guide users between conventional and more innovative geographies.

3.3. *Data design*

The disaggregated Place Survey data are not in the public domain because there would be a danger that the demographic and locational information associated with respondents may result in cases where anonymity is compromised. We took measures to maintain anonymity that satisfied LCC's Data Liaison Officer, including pre-aggregation and weighting of the data, storing them in a closed binary format and ensuring the tool did not provide access to individual records.

Respondents' addresses were initially aggregated using the established spatial hierarchy of district, ward and super output area to show responses at three spatial scales. Allowing users to identify responses from their neighbourhood was designed to help make results more relevant (R1). In phase II, we reduced this hierarchy to just two levels (district and ward) because low numbers in some areas made the data less representative and resulted in privacy concerns – something of a compromise in light of R1 and our user stories. We should emphasise that following this aggregation the ward-level resolution was higher

	Device/functionality	Phase I	Phase II
Who	Visual technique	Choice of barchart/spinebox	Spineplot as 'advanced'
	Selected responses	Red highlighting	<no change>
	Click on bar	Select responses	<no change>
	Sort	Original; count; selected count; %	As 'advanced'
	Scale	Count/selected count	As 'advanced'
Where	Visual technique	Map & rectangular cartogram	<no change>
	Spatial units	3 (district; ward, LSOA)	2 (district; ward)
	Map colour	% responses; mean `what'	% as 'advanced'
	Place search	Type place to identify	<no change>
	Click on area	Select responses	'Advanced' only
	Legend	Legend; frequency legend	Frequency as 'advanced'
What	Likert charts	No hierarchy	2-level hierarchy
	Highlighted subset	Red highlighting	<no change>
	Click on bar	Select responses	<no change>
	Click on graph	Expand (& recolour map)	<no change>
	Sort	Original, mean, consensus, selected mean and selected consensus.	As 'advanced'
	Scale	Count/selected count	As 'advanced'
	More information	<none>	'W' for web link
Overall	Mouseover	Absolute numbers	Percentages. Instructions.
	Selection	Only subset by one thing	<no change>
	Change mode	Key press	As 'advanced'; key press or click button
	Help	<none>	Tutorial.
	User logs	<none>	Log interactions
	Description of view	<none>	Simple statement that summarises current view

Table 2. Phase I and II functionality

than is currently used in the standard high-level reports in which data are released by district.

The set of Place Survey respondents was not entirely representative of the county as a whole. Weights had already been allocated to records to reduce bias from over- and under-represented respondents (CLG 2009a). We used these weighted results, in line with LCC protocol when reporting details of the Place Survey. As well as providing more representative results, an additional advantage afforded by our highly visual representation is that actual numbers were not disclosed – here we '*push out the boat*' in terms of VD1 by requiring users to rely upon visual representations of numbers and their comparison to make sense of the data whilst helping allay some of the privacy concerns with small subsets of data.

4. Visual Design

These principles and perspectives guided design decisions through which we developed the data sketches into a highly interactive and fluid design in light of the requirements. This was achieved by combining techniques for visual design and interaction from cartography, information visualisation and graphical statistics.

4.1. *Faceted high-level layout*

To facilitate the study of how attitudes, opinions and service delivery vary geographically and by section of society, we selected an initial design that separates the 'what' (opinions on the services surveyed), the 'where' (geographic characteristics of the data – the 'Place' component of the survey) and the 'who' (respondents' characteristics) facets of the survey.

Figure 2. Place Survey layout: 'what', 'where' and 'who' panels are arranged from left to right. 'What' shows the responses for five questions as bar graphs; 'where' shows mean responses to 'access to services' as a rectangular cartogram; 'who' shows the demographics of the respondents with bar graphs. Available at `http://www.lsr-online.org/placesurvey.html`

Figure 3. As Figure 2, but with respondents with 'very good health' selected as a subset. The selection is shown in light red in the 'who' panel (right) with dark red bars showing the selection alongside results for the whole survey in this and the 'what' panel (left). The 'where' panel (centre) shows only the selected subset

This high-level physical separation through which alternative ways in to the data can be established is in line with our visual design guidelines (VD1 and VD4). It enables us to address the broad range of user stories that we captured in which different perspectives on the data drove the narratives (see section 3.1.2) and provides more flexible exploration than existing solutions (see section 3.1.1). Filtering operations, as described in section 5.2, were used to link all three panels, with a selected subset consistently represented in a deep red in the panel in which it was selected and the two other views (see Figure 2). Dykes *et al.* (2010) show that combining cartographic depiction with standard interactive information visualisation is effective for exploring different facets such as these.

Figure 2 shows how we use high-level layout to separate these 'what', 'where' and 'who' perspectives into clearly identified areas of the screen (VD4), helping make the interface 'intuitive' (R3) and to 'reinforce a clear conceptual model' (ID7). As their graphical locations persist, the need for 'modality changes' (ID8) is reduced. The 'what' panel (left) shows responses to questions through a Likert scale from strongly negative to strongly positive with coloured bar charts. The 'where' panel (centre) shows how responses to the Place Survey vary geographically using a dynamic hierarchical cartogram. The 'who' panel (right) shows the demographic composition of the respondents using a series of bar charts grouped by key categories identified as significant by our colleagues at LCC. The geographic view was placed centrally as this provides the primary means for individuals to relate their individual circumstances with those of the wider group by examining data for their own local neighbourhood.

The graphics themselves are designed to be informative, uncluttered and aesthetically-pleasing (R6), with design decisions discussed in detail in the subsections that follow.

4.2. *'What'*

'What' questions captured in the Place Survey occur in a variety of forms. To simplify the interface (R3, R5), we use a consistent graphical representation for all 'what' questions. This required us to work closely with LCC to select and transform suitable questions so that their forms were comparable. A large number of the questions use a 5-way Likert scale relating to how *satisfied* or *informed* respondents feel about various issues, the degree to which they *agreed* with various statements and the *ease of access to various services*; e.g., "*very satisfied*", "*satisfied*", "*neither satisfied or dissatisfied*", "*dissatisfied*" and "*very dissatisfied*" (Figure 1). We use bar graphs for data that are ordinal and numeric to support estimation tasks (Cleveland and McGill 1984)[, VD2] and double encode with a ColorBrewer orange-purple diverging scheme (Harrower and Brewer 2003)[, VD3] centred on the central neutral response. The colouring can be considered a multi-functioning graphical element (VD1) as it acts as a legend for our geographic representations.

The 52 suitable questions identified by LCC were too many to display on the screen simultaneously. To address this, we designed a *compact form* (Figure 4, VD1) that summarises opinion along a horizontal line with a circle to show the mean value and a horizontal line centred on the circle to indicate consensus (Tastle and Wierman 2007). Clicking on a compact chart consistently expands it and reduces all other charts to their compact forms (Figure 4) – a feature for navigating the data-set introduced in our progressive tutorial (section 5.5). Clicking again has the opposite effect, helping making the action reversible (ID7).

During phase II of the design, LCC helped us group these questions into five top-level themed categories (Figure 2), each of which is characterised by a question deemed

Figure 4. Three ‘what’ depictions. *Left:* Initial view showing a representative question for each category. *Centre:* ‘Access to services’ has been expanded and its questions are in compact chart form except for ‘Access to local hospital’. *Right:* ‘Access to activities for young people’ is selected, which has a low mean value compared to the others.

representative. Using the same motivation as for the progressive tutorial, Figure 4 shows that this provides a simple initial view, where categories of interest can be selected to reveal details on demand (R1, R3, ID1, VD4). Whilst this is a modality change (ID8) we apply it consistently in the ‘what’ panel and use smooth animated transitions to relate the successive views (ID1).

4.3. *‘Who’*

Horizontal bar charts, in which labels are horizontal and thus readable, show response counts for the various demographic categories that LCC helped us define. Figure 5 shows that even exploring these linked charts alone can provide rich information about the population and their relationships with others. Mondrian (Theus 2002) was used in initial exploratory design. The software epitomises the clarity of design that we aim to achieve in our visual design principles and inspired much of the visual encoding and functionality implemented in the ‘who’-related aspects. The linked spine plots are a good example

Figure 5. Five 'who' charts. *A:* Respondents of 'very good health' have a lower age profile than all respondents. *B:* Spine plots show that these respondents comprise half of those buying somewhere to live. *C:* Respondents of 'good health' have an older age profile. *D:* Only small numbers report 'bad/very bad' health. *E:* Profiles can be determined by scaling each chart to the *selected* maximum.

(Figure 5b) that comply with guideline VD2 and show how effectively it can be applied. In spine plots (Figure 5b) vertical *height* is used to show overall counts and horizontal bars are used to compare the proportions of the selected respondents falling in each 'who' category – shaded horizontal length shows *proportions* of selected data. Whilst it is harder to estimate or compare the values represented by the non-aligned heights than in the standard bar chart, this makes proportion comparison straightforward, This layout shows, for example, how proportions of the population deemed to be in 'Good Health' decreases with age in (Figure 5b). Figure 12 shows that the respondent profile in each district is similar.

4.4. *'Where'*

The concept of 'place' was central to the nature of the survey. It provides a principal means by which an individual can relate their views of service provision to others in the county and was core to many of our user stories. As such we placed the 'where' view of the data centrally in the interface ensuring that data were searchable (R1, R3, VD5), comparable and displayable according to geography. Establishing a means of using layout within the 'where' panel to enable citizens and analysts to compare and relate the places of the Place Survey involved some of the most complex design decisions, but also enabled us to meet a number of requirements by adopting a non-conventional approach. Our solution accounts for the geography of Leicestershire and the context by emphasising population at the cost of precise geographic location (VD5), but uses animated transitions

Figure 6. The map (*left*), the cartogram (*right*) and a frame from the animated transition between the two (*centre*).

(Heer and Robertson 2007) to relate this to a more conventional geographic layout (ID1). It is described in detail below.

4.4.1. Layout

Leicestershire is a predominantly rural county with several large market towns that contain significant centres of population, and 'urban creep' into the areas that adjoin the central city of Leicester, which is governed by a separate local authority (Leicester City Council). The low level spatial units used in local government and to aggregate data such as that collected in the Place Survey are designed to make populations roughly equivalent for democratic reasons. Given the uneven population distribution, this results in units of very variable size. Consequently, rather than using the geometric GIS default – the choropleth, in which visual salience relates to land area rather than population – we use a population cartogram (Tobler 2004) to represent information about society in a manner in which all people are equally represented and (approximately) equally salient. The cartogram uses symbol area to relate to population and so other visual variables can be used to show additional data – in our case the opinions of those selected. We colour each place with shades from the 'what' panel (VD3) – as depicted in central legend – showing how the mean response of the 'what' question selected varies across the county and in particular its population.

The administrative hierarchy or Leicestershire consists of seven districts, each of which have local governance and a degree of separation in terms of policy, funding and perhaps attitude. Districts are important to LCC, and to citizens who are represented politically at district and county level. It is thus important that our cartograms are hierarchical – providing the local detail in novel accessible ways, and also facilitating comparison within and between district. Dorling's classic portrayal of British society (Dorling 1995) uses circle symbols to represent areas. We retain this 'common shape' approach, but use rectangles of restricted aspect ratio, the sizes of which have been shown to be comparable (Kong *et al.* 2010), as these nest. The nesting afforded by rectangular cartograms (Raisz 1934, van Kreveld and Speckmann 2007) takes advantage of the container schema, in which a strong boundary allows us to distinguish interior from exterior and thus items that are within (district) or beyond – much as we do in the high level 'who', 'what', 'where' layout. MacEachren (1995) cites Lakoff (1987) in identifying this as a strong image schema that is used widely in cartography. By nesting wards that occur within districts and separating districts from one another we show the two-level hierarchy with clear linear boundaries, enabling the populations and attitudes of districts and wards to be considered and compared concurrently (VD4).

Whilst this representation retains some geography we evidently lose lots of geographic detail and present an alternative geography that is unfamiliar – accommodating VD5, but potentially compromising R3 and R5. We address this novelty / familiarity tension by also providing a more conventional geographic view in which symbols sized by population and coloured by survey response are located at the centres of their associated spatial units in a more conventional geographic layout. These proportional symbol maps show geography with more accuracy than our cartograms but suffer from some occlusion. This is apparent in Figure 6 (left), where symbols used to show opinion overlap in the more densely populated areas. In essence, when comparing the rectangular cartogram with a choropleth we trade ability to interpret and relate geographic location and extent for ability to estimate and relate population – with area outperforming colour visual variables for elementary tasks according to Cleveland and McGill (1984). But in the proportional symbols map we add geographic accuracy at the cost of population estimation – as our proportionately sized symbols overlap. We do not use framed-rectangle charts (Cleveland and McGill 1984) due to the very variable sizes of the units used and this particular design proposal not accommodating estimation at more than one scale. This combination of more familiar and more abstract geography is designed to "*push out the boat*" in a manner that promotes consideration of the survey in its societal context as well as its geographic context and helps users relate the two. It enables citizens to see how the views and populations of their immediate locality (ward) compares with others in the county and the district and also how their district compares with others. The two layouts are introduced as part of the progressive tutorial (see section 5.5) with animated transitions (Heer and Robertson 2007) used to smoothly lead from one representation to another in a fluid manner (ID1) in an attempt to introduce new population-based perspectives on the county "*by stealth*".

Our non-conventional cartography received positive feedback from our colleagues in LCC, particularly when used in conjunction with the more familiar geography. We also experienced evidence of learning from this unconventional representation, despite our colleagues having considerable knowledge of Leicestershire and familiarity with data that describes the county. For example, some surprise was expressed at the dominance of Loughborough (Charnwood district) made evident from the cartogram. This should not be too much of a shock as members of the LCC team expressed representational needs that gave rise to the algorithm through which these layouts are produced (Wood and Dykes 2008) during a previous collaboration (Lloyd and Dykes 2011) and have used them in documents involved in local policy development (Leicestershire County Council 2010).

4.4.2. Mapping opinion

Because the Place Survey focusses on local neighbourhoods, spatial variation of opinion is important. We used the same diverging colour scheme as in 'what' to colour spatial units by their average opinion, with the same assumption of an evenly-spaced ordinal scale as used for the summary Likert charts. In Figure 3, opinions on access to services for people of 'very good health' are mapped.

4.4.3. Legend and explanatory text

We provided a compact statistical legend. To increase its information-carrying capacity (Dykes *et al.* 2010), and produce a data-dense multifunctioning element (VD1) an integral histogram showing the distribution of values was added (Kumar 2004), along with an arrow indicating the value of the place indicated with the mouse cursor. To supplement the legend a textual summary of the current view was placed below it (see for example, Figures 2 and 3). This has two purposes. Firstly to reinforce the centrality of the spatial view at the centre of the graphic, the statement provided a single brief summary of the user's current view of the Place Survey. Secondly it provides an important 'analytic navigation aid' during the process where the user is likely to be filtering by a range of different variables. This was raised as an important issue during requirements and feedback workshops to address R2, R3 and R5.

5. Interaction and Narrative

Achieving the kind of fluid visual exploration to which we aspire here requires close links between visual design and interaction design. We have already introduced some elements of interaction used in our design, but here emphasise these features and their use, in conjunction with visual design elements and decisions, to develop narrative. We deemed this to be an important means of ensuring that the interface was relevant (R1) to a range of users (R5) in the context of our diverse user stories, whilst addressing high-level requirements that might otherwise be in conflict R2, R3, R4, R5 and R7.

5.1. *Themed Layout*

We have already described the high-level design, involving a layout through which 'who', 'where' and 'what' approaches to information seeking are presented and can be explored (section 4.1). This provides the user with three accessible and alternative routes in to the Place Survey. This gives users a straight but limited choice of structured options through which they can begin to engage with the data and may aid them both in relating the data to people, places, or characteristics that are of particular interest and in developing a narrative through which to structure their otherwise open exploration (R3, R5 and perhaps R7). It supports the kinds of user story captured in our requirements exercise.

5.2. *Selection and Filtering*

Filtering – a process of selectively removing data that is not of interest, or emphasising data that is particularly pertinent – is a common and fundamental part of the visual analytic process (Chi 2000). In the geographic realm spatial filtering is often achieved through zooming and panning while simple attribute filtering can occur through layer selection. More sophisticated filtering may be applied via focal operators on raster data structures or database query operations for object and relational data models. Effective filtering can become complex (Wills 1996), especially in systems that permit cross-filtering operations whereby multidimensional filters are applied in an effort to precisely remove data that are not of interest (Weaver 2010). Yet the notion of filtering as part of enquiry is a natural one and is particularly suited to allowing the individual to relate their personal situation to a larger group – "*just show me data about people like me / in my location / in my area of interest*". This provides a means by which general users can participate in the process of filtering without the need for complex interfaces (e.g., Your Health Profile[1]).

In the Place Survey tool, a subset of respondents can be filtered though 'direct manipulation' (ID3) by clicking on a category in any of the panels – for example, 'very good health', a question response a particular place. This provides immediate means to

[1] `http://fathom.info/yourhealth`

make results more 'relevant' (R1) as users can select subsets corresponding to their area, their demographics or their opinion on a particular issue. All symbols representing data are clickable (ID3) and when interacted with their saturation increases to signify their activation (ID2). A click results in a question, a group or a topic ('what'), a district or ward ('where') or a population characteristic ('who') being selected with updates across the panels.

In Figure 3, respondents with 'very good health' are selected and this subset is reflected immediately (ID2), in a distinguishable deep red, in all three coordinated panels using animated transitions (ID1). The filtered selection is always displayed alongside the results of the whole survey in the side panels, enabling characteristics of the subset to be compared to the survey as a whole. In the 'what' panel, the mean is shown as a circle and degree of consensus is represented by the length of a line centred on the circle. In Figure 3, the demographics of 'very good health' respondents can be seen to be younger than for the whole survey. The spatial variation in opinion is slightly less neutral, but not markedly so.

In a multidimensional dataset such as the Place Survey, there is a design tension between the precision afforded by cross filtering (for example, "*show me the views of this service from people who live here, who have this health status and are this age*") and the complexity of interaction this requires (i.e., between requirements R3 and R1/R4). Cross-filtering can raise privacy concerns as this precision allows identification of individuals or very small groups. Generating progressively smaller subsets also quickly results in 'dead ends' (ID6) which we wish to avoid. We therefore elected to keep filtering simple, whereby data can only be filtered by a single variable at a time. Clicking on a filtered category reverts the subset to encompass the whole survey, effectively 'undoing' the filter making the filtering operation 'reversible' (ID6). This decision followed considerable discussion with our colleagues at LCC as we aimed to achieve the appropriate balance between functionality and complexity for this context and in light of concerns about possible disclosure through cross-filtering.

5.3. *Orientation*

The requirements workshop identified the importance of using familiar names of places, rather than the less well-known administrative units, to ensure the georeferencing remains relevant to the citizens of the county (R1). Whilst citizens do not associate themselves with the names of wards or smaller administrative areas, postcodes (at all scales), the names of districts, and town names used in the names of wards and LCC's super output area nomenclature (Leicestershire County Council (LCC) 2008) are widely recognised in Leicestershire, so we provided the means to search for these.

This type of interaction can become unwieldy if the geometrical reference frame changes frequently through zoom and pan (ID8), though overview maps and the option to zoom to the full extent can help. We maintained a static map frame and simply identified matching areas using a low opacity fill so that multiple matching areas at different levels of the administrative hierarchy can be identified (Figure 7). We included levels below that at which we presented Place Survey data. Overlapping symbols result in higher levels of opacity and so the greater association that a (multiply) named place has with a search term the darker it appears. Clicking anywhere clears this superimposed layer identifying the relationships between locations and named places, returning the map to the previous appearance. This interaction was developed from an early design sketch and subsequently incorporated into the final design.

Figure 7. Places containing the text "wood" have been identified, including the district of Charnwood and Oadby Woodlands ward.

5.4. *Reordering and Rescaling*

Graphics in which order is important (VD2), such as those in the 'what' and 'who' side panels, can be re-ordered using a number of criteria (see Table 2) through simple interaction. Enabling users to order data gives them some control over the way that the survey is read – effectively adding narrative to the survey results. When data are filtered and ordered by particular characteristics, changing the filter changes the ordering. In such cases animated transitions are used to re-sort charts according to the updated selection. Animated transitions used in this way help to maintain the fluidity of the interaction (Elmqvist *et al.* 2011) but perhaps more importantly are likely to ease the cognitive load in interpreting the newly transformed data (Heer and Robertson 2007). They also highlight differences in successive orders and thus support comparison. Bars in the 'what' charts can be sorted by average opinion or level of agreement. Bars in the 'who' charts can be sorted alphabetically or in descending order of count, selected count or selected ratio. Charts in both side panels can be scaled to the maximum selected value – useful if selected subsets are too small to visually resolve (Figure 5e).

5.5. *Progressive tutorial and interface*

One of our most important requirements was to make the interface suitable for a range of users (R5). As we have established a number of times, this is difficult to achieve given the somewhat contrasting needs to be innovative and to "*push out the boat*" in terms of visualization design – a challenging and seemingly contradictory set of requirements. We wanted to allow casual users to obtain information in intuitive ways with minimal interaction, but also to provide rich functionality (R4) to those who look for it, in such

Figure 8. Geographical variation in opinion about local bus services, from 25–35 (*left*) and 66–75 year olds (*right*) as stated by the summary sentence. ‘What’ charts sorted by average opinion of each group. 66–75 year olds tend to be more satisfied, except in some of the district peripheries.

a way that it does not compromise simplicity of use. We also hoped to help casual users learn how to use the interface in more sophisticated ways through their interaction with it.

Design decisions to limit filtering of variables, to hold the faceted visual layout constant and to afford interaction though direct manipulation of data symbolisation were targeted at causal users. For more sophisticated interaction we made further analytical capability available through an ‘advanced options’ mode (section 5.5), which needs to be ‘discovered’ before use. Although ID8 warns against modality changes, we deliberately wanted to disable non-essential functionality until the user explicitly ‘opted-in’ – so that this would not be invoked accidentally. When in advanced mode, rudimentary ‘buttons’ are shown at the bottom of the screen, grouped below the relevant ‘what’, ‘where’ and ‘who’ facet panels. ‘Direct manipulation’ (ID3) was not appropriate here, so we tried to ‘integrate user interface components’ into the design (ID4). Details of each are indicated in the tooltip, invoked through a mouse click or a key press. When invoked, an alert indicates what has happened and how to return to a previous state to ensure users understand what has happened and why, ‘proving immediate visual feedback on interaction in real-time’ (ID2).

Decisions on which functionality to consider *core* and *advanced* were informed by discussions with LCC during our inter-phase feedback workshop (Table 2). Core functionality is that which we regarded as essential for minimal use of the Place Survey, whereas advanced functionality provides the richness of exploration that we wanted to support and to which we hoped our ‘minimal use’ users would aspire (R4). Separating these two types of functionality enabled us to design for a range of users, beginning with a simpler interface but allowing more advanced users the functionality they require to obtain more in-depth insights once they had gained experience of the data, its representation and the various interactions.

Pilot testing of early prototypes with volunteers revealed that some interaction could be *accidentally* invoked – resulting in confusion. ‘Advanced functionality’, invoked through keystrokes and useful in design experiments and testing, was thus disabled (unless explicitly enabled) for this reason. Unintended interaction in the early prototypes also occurred with *place selection* (“*where: click on area*” in Table 2). In both the ‘who’ and ‘what’ panels, clicking replaced the current selection with a new subset. To help ‘reinforce a clear conceptual model’ (ID7), we initially extended this behaviour to the ‘where’ panel (i.e. clicking on an area should select all the responses from that area). However, as selecting responses from one area results in lack of data for most of the map (e.g., Fig-

Figure 9. Four of the seven stages of the progressive tutorial that successively introduce 'what', 'who' and 'where' perspectives on the data, encouraging users to develop alternative narratives.

ure 12b), and the map view is so dominant, a first-time user may not understand what they have done – even given the textual description. We therefore chose to disable this functionality in the 'where' panel until the user had gained more experience of the way the tool worked, moving this to 'advanced functionality' – a design compromise due to a problem associated with consistency of response highlighted by our testing.

These and other aspects of the interface are explained and can be revealed through a staged tutorial, which introduces layout and reveals sections of the interface and interactions progressively. Figure 9 shows elements of the interface being revealed in stages through the progressive tutorial – starting with a short textual introduction, followed by a description of each panel in turn with layout and then interactions described. The simple instructions using a large but serifed font suggesting narrative rather then 'technical manual'. The invitation to try out interactive functionality deliberately blurs the boundary between tool and tutorial. This follows the guidelines of 'playful design' (Ferrara 2012) common in gaming where players are inducted through safe tutorial versions of the game that gradually increase in complexity and challenge. Here, each page is a fully interactive, yet simplified form of the interface. Functionality is progressively added so that the interface develops until the user either exits or completes the tutorial. The progressive freedom for the user to explore the application follows the 'Martini glass' narrative model for visualization of Segel and Heer (2010). The application always starts with the tutorial opening page – the narrow stem of the Martini glass – but allows users to step into the application at any stage with a key-stroke, thus enabling experienced users to access full functionality quickly. The wording of the narrative used to guide and link these pages was refined in consultation with LCC and a number of volunteers.

6. Visual exploration examples

This interface provides access to a mass of information recorded in the Place Survey that can be filtered in a multitude of ways. It allows us to see that the views expressed on local services vary geographically and according to types of people. We can identify individual outliers and more general trends and relate these to people and place. Here we offer some examples of the kinds of pattern that can be revealed. These examples are not unrelated to the user stories introduced in section 3.1.2 and are based upon activity undertaken by LCC analysts using the system. They act both as a form of validation of the design itself (especially with respect to R2, R4 and R5) and a specific demonstration of the potential that this kind of data visualization interface offers to a broad range of users of citizen surveys.

6.1. *Public involvement*

Crucial to citizen influence in the way local services are run is that the public knows how to get involved in local democracy. The Place Survey questions on public involvement helped establish the extent to which citizens of Leicestershire felt informed. The ordered 'what graphs' in Figure 10a (left panel) show that of the questions that ask how informed citizens feel about involvement, on average citizens are most informed about how to vote and least about what to do in an emergency. Consensus of opinion is relatively consistent amongst these questions. The geographical distribution of 'informed about how to register to vote' (the selected question) varies little and its average is positive (shown by the geographically consistent purple colour in Figure 10a) for each area – crucial for ensuring that democracy is maintained. However, selecting age groups in turn in the 'who' panel (right panel of Figure 10a) shows that the degree to which citizens feel informed increases with age and that younger citizens in some of the larger rural villages and market towns feel less well informed (Figures 10b and 10c) – the kind of patterns that concern local authorities and could result in policy change. Knowledge about other forms of public involvement are generally negative with citizen influence lower that one might hope. The negative response to the question of what to do in a large-scale emergency is also spatially consistent (Figure 10d) but shows positive variation with age.

Figures 10e and 10f compare those in publicly-rented accommodation with those in privately-rented accommodation. Those in privately-rented accommodation are less informed about voting. Looking at their age profile allows us to see that these citizens tend to be in the younger age categories, allowing us to assess interactions between 'who' characteristics. The ease with which variation in the responses for this question can be explored has enabled LCC to identify groups of citizens and areas and area types in which to target awareness campaigns.

6.2. *Access to services*

Figure 11a shows that shops are the most accessible service on average. There is a high degree of consensus and this is fairly geographically invariant. It is also evident that the degree of consensus as regards access to services decreases as overall levels of agreement decrease, with the lowest agreement score for accessibility to 'activities for young people' (Figure 11d). As agreement and consensus decrease, there tends to be a greater spatial heterogeneity in responses and 'access to activities for young people' is evidently viewed differently amongst the population (Figure 11d, left panel). This is one of the questions for

a b

c d

e f

Figure 10. Exploring public involvement by geography, age and occupancy

which men and women provide different answers in terms of opinion and geography. This example shows how a narrative can be quickly developed through the interface: focus on services, identify those to which people think access is more difficult and opinion divided, consider the geography and the characteristics of those who offer opinions. Another example involves views on ease of access to theatre or cinema, which are geographically divided in the county. Those in the Charnwood and Melton districts seem best served, but men in the south and west of Harborough, particularly in the wards of Lutterworth, seem to find access to these services most challenging ('fairly difficult').

Only one ward rated public transport access 'fairly difficult' (Figure 11b), a number of places considered access to hospital facilities 'difficult' (Figure 11c) and the geographic picture was mixed for 'access to activities for young people' but relatively neutral (Figure 11d, centre) showing that perceived access is more about 'who' than 'where' in this case. Exploring how this was related to the age of participants shows the views of younger people (Figure 11e) to be more polarised than for older people (Figure 11f), but with a

a b

c d

e f

Figure 11. Exploring access to services by age and geography

similar spatial pattern. One might expect younger participants to have more experience of 'activities for young people' but also to find access to them more challenging, particularly in areas that are not served well by public transport. This kind of analysis has helped suggest to LCC where access to activities for young people, and under-represented group, need to be improved.

6.3. *Differences in public service quality between districts*

Some services in Leicestershire are devolved to the seven districts. Data can be displayed by district (rather than ward) in the 'where' panel as 'advanced functionality' Figure 12a), showing, for example that citizens of the rural Harborough district are less satisfied about local bus services than residents of other districts where population is less dispersed. As well as aggregating to meaningful geographical regions (districts) the bigger areas involved result in larger sample sizes.

a b

c d

Figure 12. Differences in public service quality between districts

Functionality enabling responses to be subset by area was also allocated as 'advanced' for the reasons given in section 5.5. Filtering by district shows that whilst opinions on some public services are relatively stable (e.g., Fire), there are marked differences with others. Local buses, for example, are ranked half way up the ordered list of public service satisfaction in some districts; in others they are ranked amongst the lowest (Figures 12b, 12c and 12d, left panel). The geographic proportionate symbol map shows those living in more remote areas to be least satisfied whilst the cartogram at ward level reveals that these citizens comprise a relatively small proportion of the county's population.

This type of exploration helps establish whether public services are of the same quality in all areas. The results here suggest that some perception in bus service provision is strongly geographically controlled. By allowing citizens to compare their own experience of such provision with that elsewhere in the county, and to relate the numbers of people in the areas for which services are provided, the tool supports citizens in holding service providers to account. Recent budget reductions and a countywide consultation exercise[1] have sharpened views on these kinds of issues and made both this type of comparison and public access to this kind of information all the more important.

7. Use

The application was made available through LCCs 'Leicestershire Statistics and Research Online' website [2] in June 2010. We passively monitored its use from this time by logging

[1] `http://www.leics.gov.uk/future.htm`
[2] `http://www.lsr-online.org/`

Figure 13. Activity by user groups. *Left:* Length of grey bar indicates session (use) count by user group. Green indicates whose who have made at least one selection. *Middle and right:* For those who have filtered at least once, median session length is indicated with the vertical line. Dark grey shows 5^{th} and 6^{th} deciles, mid grey shows 4^{th} and 7^{th} deciles, light grey shows 3^{rd} and 8^{th} deciles.

keyboard and mouse interactions with the application, to provide information about usage patterns whilst not interfering with user activity. This allowed us to monitor real interactions with the tool following its release, but inevitably led to limitations – for example, personal information was limited to IP address. We discarded sessions from our institution and aggregated the rest into two groups relating to geography: Leicestershire (L), National (N; UK) and international (I; other). Each of these were split into user types: government (G) and public (P). The resulting 6 groups are denoted with combinations of these letters henceforth. We knew the IP address range for LCC and GeoIP helped us indicate other geographical groupings, with the caveat that it can only resolve UK locations 56% of the time[3]. We expected users most local to Leicestershire to be most interested in the data themselves and we expected government-based users to be more interested in data exploration than other citizens.

The headline finding is that the application has been underused. This means that we are unable to validate design decisions in terms of our broad target group audience and that we can make no claims as regards to the Grand Challenge introduced in section 1. The page had 2,495 views, yet we only logged 1,714 sessions. This shortfall may comprise users who deliberately aborted the applet's startup (the 912kb applet could sometimes take 10 seconds to load) and those whose browsers were unable to start the applet (Java is generally not available on smartphones and tablet devices). About half of all sessions did not select any data – many of these are likely to relate to abortive uses. The duration and interaction information collected in sessions in which data were logged is shown in Figure 13 and some inferences can be made based upon this. Of our key targets, the Leicestershire citizens group (L-P) is under-represented with very low levels of engagement. Figure 13 shows that of the 1,622 sessions allocated to the 6 user groups between June 2010 and March 2012 these users participated in just 7% of activity – a little over 100 separate events. It seems that the citizens of Leicestershire were either unaware or uninterested in the application, the data or both. Just 60 distinct IP addresses were referred to the application from the LCC website, raising questions about how effectively it was promoted to our target group by the host organization. Indeed, the greatest single source of users was the Information Aesthetics[1] blog (413 referrals) shortly after the application featured there – with these users not being members of our target groups. The application was, however, regularly accessed from within the local authority and many of the sessions undertaken by users with IP addresses within the LCC range

[3] `http://bit.ly/H6efgt`
[1] `http://infosthetics.com/`

Figure 14. The tutorial page reached by users and what they went on to do. *Left:* Most users deliberately exited the tutorial (blue) but some remained on the page and ended their session there(grey). *Other charts:* Medians are indicated with the vertical line. Dark grey shows 5^{th} and 6^{th} deciles, mid grey shows 4^{th} and 7^{th} deciles, light grey shows 3^{rd} and 8^{th} deciles. Graphs are scaled from 0 to highest value of 8^{th} deciles for any user group.

were of longer duration than those of other groups. Indeed, government users can be seen to filter by more variables and engage in longer sessions than other users (Figure 13) – perhaps suggesting that the design engaged the group involved in its development more successfully than the wider group whom it was hoped would take advantage of this novel approach and exploratory capability.

7.1. *Facets and functionality*

As expected the most used functions were selection by ‘who’, selection by ‘what’, question mapping and expanding ‘what’ categories. The six groups used these in roughly equal proportions, but LCC tended to ask ‘what’ questions with greater frequency suggesting a difference in emphasis amongst the angles of analysis undertaken by local authority users. Selection by ‘where’ was presented as ‘advanced’ functionality and notably less popular than other faceted enquiries as users had to ‘discover’ it and switch it on. However, its low use by the LCC group (10% of their sessions), which contained users who knew about the functionality having been directly involved in its development, and the decision to switch this capability off initially suggests that the core functionality met most of the local authority analysts’ needs.

To represent ‘where’ opinions were located we provided the rectangular cartogram by default, showing how users could switch to the more familiar but overlapping proportional symbol map in page 5 of the tutorial (seen during 579 sessions). The proportional symbol map was only used in 292 sessions, perhaps indicating that users found the rectangular cartogram interpretable – or alternatively that the means of transforming to the geographic map was hard to find. It would be interesting in future to default to a more familiar geography and see whether people switch to the rectangular cartogram.

Use of the place finder was low (153 sessions), yet 539 sessions saw it described in the tutorial. This might suggest that users did not find a need for this form of orientation, that was deemed important in our exercises to establish requirements and to support users in establishing a relevant (R1) personal narrative. The fact that this feature was used most frequently in sessions logged by Leicestershire-based users (L-P=19%; N-P=10% and I-P=8%) gives some support to the not unreasonable notion that this kind of orientation is most appropriate for those who know the area in question well. We have already indicated that this was the case for a small proportion of the users whose sessions we logged.

7.2. *Tutorial*

We recorded the extent to which the tutorial was used in the logged sessions and are able to interpret this information to make some suggestions as regards design and usage. Figure 14 shows that most users either *used the entire tutorial*, viewing all pages, or *did not use the tutorial* at all – exiting from the introductory screen. Of the sessions where the tutorial was *not* accessed, over two thirds of these skipped the tutorial from the opening page to start using the tool directly. Some of these will be repeat visitors already exposed to the tutorial. The remainder were abortive users who proceeded no further than the introductory screen. Our design was intended to encourage first-time visitors to discover functionality gently and to enable return visitors to reach the end of the tutorial (all panels visible and full functionality available) quickly. The 30% of sessions involving completion of the entire tutorial are likely to have been by choice as the option to skip the tutorial at any time was prominent. The length of time and number of interactions during the tutorial, as shown in the central three graphs of Figure 14, suggest that many users used this device actively. Pages 4 and 6 encouraged changing the map view and finding a place, hence the increased activity in Figure 14. This also suggests that by the time the tutorial had been completed, users who had done so would have been familiar with the cartogram and geographic layouts that we used. All in all, the fact that the majority of users either ignored or completed the tutorial, the way in which interactions occurred during the tutorial, and the evidence that a minority or users were able to exit the tutorial mid-way through suggest that this device worked reasonably well. Although our inability to relate users across multiple sessions does not enable us to evaluate the success of the Martini glass approach to introducing functionality fully, this is the kind of usage pattern that we might have hoped for had it been successful – with a greater number of returning users exiting the tutorial at the outset had uptake levels been higher.

8. Reflection

The very limited uptake of the application means that we are unable to use the logs to evaluate robustly from the perspectives of the broad range of users for whom we were designing. However, we can reflect upon the design decisions in relation to our original requirements (Table 1) as informed by this information.

Relevant (R1): Offering ways of considering the data and developing narratives based upon the 'who', 'where' and 'what' facets was designed to help meet this requirement. Selection was limited to just one characteristic and 'where' selection as an advanced option to simply the interface (R6). This may have caused selections to be less relevant than otherwise, but the logs show that even those who completed the tutorial or participated in sessions from within LCC (and so were more knowledgable about advanced functionality) used the 'where' facet to a limited extent. We expected 'where' to be most relevant to citizens of Leicestershire. This is an established means of making information relevant and the digital provision of survey information such as this enables those browsing information to generate very personal summaries. The place finder, which used a variety of place name lookup lists, was also designed to help meet this requirement, but its use was limited. This might have been because our decision to report results at the relatively coarse ward-level may have encouraged broad overviews rather that user-centric findings. Additionally we did not provide a direct link between place finding and highlighting, a feature that we could explore. We need to consider a larger number of local users to draw conclusions on the success or otherwise of the 'where' facet and on the importance of place in providing relevant information to citizens.

Informative (R2): We met this requirement as shown by the visual exploration examples in section 6, whilst acknowledging that this depends on the question. Usage logs indicate that selections that support a range of enquiries that we can relate to the kinds of user story that we developed were made, but we cannot be sure how many were intentional. The tool helped LCC answer their questions. The research team leader used it to discuss the provision of activities for young people with a local community group and another employee used it to answer questions about how different services are perceived in different wards. So we have some evidence that our functionality met this need in the local authority but less that this kind of information use is appropriate more widely.

Intuitive (R3): The usage logs showed that people were able to use the core functionality. An LCC employee not involved in the design found that "*it was useful contextual information to feed into a project*" and regarded our solution as "*easier than the alternative ways of accessing the data*". This is a success given our consideration of existing solutions and application of interaction and visual design principles to provide access to information. The progressive tutorial was designed to introduce functionality in an intuitive manner and usage logs suggest that this was effective – the staged introduction and ability to explore data *during* the tutorial in a simplified interface seemed successful. Repeat visitors were able to skip the tutorial, but we have limited information about those who had difficulty using the interface. An LCC employee suggested that we should have "*focussed on particular parts of the survey rather than all of it*" and there should have been "*less data/fewer cross-tabs of the data*". Requirements R4, R2, R1 and our ambitious remit may have resulted in over-stretching here. In retrospect, we might have been better to focus on particular parts of the survey rather than all of it. To an extent this contradicts the 'power of visualisation' message that drives the academic community (Thomas and Cook 2005), but introducing powerful methods through small scale examples may be an effective educational device when spreading the message more widely – the Martini glass narrative model applied at a far larger scale. We considered low cost means of guiding users to functionality, with alternative and themed entry points and interactive tutorials using personas and videos as a means of low investment training. These were not possible given the scope of the project, but we consider them to be important contributions to intuitive information design.

Rich functionality (R4): We didn't find it difficult to convince our LCC colleagues that the visual approaches we applied resulted in rich functionality. Indeed, even the core functionality provided rich means of exploring the data with a low barrier to use for those who engaged with the tutorial. Richer functionality was partially hidden in the advanced option, which was introduced in an open ended manner at the end of the tutorial and as reported above. This was used infrequently, though more so by those accessing the application from within LCC than others.

Suitable for range of users (R5): This is an important requirement in the context of our initial objectives and ambitions, but one for which we have little supporting evidence. The log data that reveal lower than anticipated levels of use of the tool by citizens of Leicestershire and as such limit our abilities to draw firm conclusions about the effects of ambitious data design in which needs for an analytical group of users are used to "*push out the boat*" in terms of information design for a wider group of citizens. We attempted to support a variety of users with the staged tutorial and the (under-used) advanced functions – a design intended to make sophisticated and novel methods or engagement widely accessible. However, we did not capture as wide a group of users as we had initially hoped. We see no evidence in the logs that we lost users from Leicestershire during the tutorial or through any specific functionality or feature, or indeed that they behaved particularly differently to our other users, apart from a tendency to associate enquiry with aspects of place. We simply failed to get many of them to use the application in the first place. This is in contrast to some of our other experiences in public participation projects (e.g. Slingsby and Radburn 2013). It suggests a need for more effective publicity and perhaps citizen input, or at least establishing buy-in from key citizen stake-holders, in the requirements and evaluation stages of the work. It also leads us to consider the importance of the Place Survey as a source of information for citizens. That the initial requirements gathering and phase I evaluation was conducted with LCC staff rather than citizens directly, likely resulted in high levels of satisfaction amongst users in LCC but perhaps a tool that was less appropriate for casual use than we had hoped.

Aesthetically-pleasing (R6): Aesthetics were important to the design and our use of consistent muted colours, white space and 'the data are the interface' contributed to this. PlaceSurvey was featured on the Information Aesthetics blog[1] where aesthetic is an important criterion and we received plenty of positive feedback on the look and feel of the design from our LCC colleagues. A lack of engagement with the wider public means that we are unable to draw strong conclusions here.

Fun (R7): If we exclude users who did not make any selections, the median session duration for the public (L-P, N-P and I-P) was just over 3 minutes, rising to 20 minutes for the 8^{th} decile, providing some evidence that the application is either fun or engaging. We should also emphasise here that in light of the project objectives – to use sophisticated functionality to engage citizens – supporting a small percentage of users in engaging activity can be deemed a success, and 20% of users were using the interface for more than 20 minutes. However, as indicated above, this small percentage is a small number in this case and so does not provide strong evidence that the tool was fun or engaging. Again, LCC colleagues involved in the design steered us towards this objective and seemed satisfied – providing anecdotal positive feedback during the design stage and subsequently.

9. Conclusion

The aims of this work were broadly twofold. Firstly they were to explore means of using visualization to provide access to information in ways that support both those in government and those who are governed in using data on perception of service provision more effectively. The desire here has been to make sense of the data to support policy and in a way that encourages active influence on local decision making. We did so in the context of Leicestershire County Council's requirements to provide its citizens with access to the results of the Place Survey. Secondly we aimed to provide a case study of good practice and lessons learned to inform those designing data-rich geospatial exploratory interfaces to the results of citizen surveys for widespread use.

We cannot provide evidence to show that the first of these has been achieved – indeed the logs show the level of engagement with the design by citizens of Leicestershire to have been very limited. Whilst the design was well intentioned, and as we have shown here well considered, we can't claim to have contributed to achieving Munzner's Grand Challenge (Munzner 2008). However, we do have evidence that the application has been

[1] `http://infosthetics.com/`

used in a variety of ways by the local authority to explore and derive knowledge from their data in ways that have informed local policy and may have an effect on future service provision. For example, PlaceSurvey informed a locality asset model developed to improve access to services in the county. An LCC colleague, not directly involved in the design, informed us that the tool "*enabled the Place Survey to be easily interpreted so that we could understand issues for specific demographics within the locality at ward level – which fed into the proposal for an integrated model of service delivery*". So, whilst the tool has been used in a very limited manner by a very limited number of citizens, we have provided exploratory visual capability that is having some effect within the local authority. We have undeniably been more successful in supporting analysts within the local authority than in increasing public scrutiny of the data, although we would argue that the public do now have this facility. The second aim involves documenting the design in the context of perceived needs as expressed through LCCs requirements, providing it for others to use and offering reflection upon the design and design process as we have done here. We consider the user-driven design, evidence of post-deployment use and subsequent LCC validation to be indicative of some success in a complex design exercise on which we have reflected in some detail.

In presenting this work we claim a number of contributions. The first of these has been to make a reasoned case for web-based interactive visualisation rather than simply releasing open data. Although the barrier to analysing open data is now lower than ever before, environments for analysis are out of reach for most citizens and even for those for which analysis is possible, is time consuming. The fact that LCC itself used the Place Survey tool to facilitate quick comparison for various internal reports and in understanding local issues to inform policy is testament to at least the analytical and communicative benefits of such an approach. Although the recent drive for open data is very welcome, we have argued that this alone is not enough to inform or empower citizens. People need both the means and the motivation to invest effort in understanding and analysing data. A rich but accessible visual tool is one way of providing the means, and guiding people carefully through its use along with the ability to relate an individual's personal situation to the wider group may provide the motivation. We have also argued that visual interfaces can be used to overcome some issues of data privacy by using aggregation and a structured set of selection and filtering operations to prevent access to individual records while at the same time maintaining rich analytic function. However, whilst we have some evidence that those with experience of and professional interest in data analysis found the design effective these arguments remain hypothetical. We have not succeeded in drawing large numbers of citizens to our visualization, though which we can evaluate these ideas fully and provide no evidence that the forms of narrative and interaction that we developed were successful in opening the door to more sophisticated analysis. Our failure to draw citizen users to the tool severely limits our ability to draw conclusions here, other than as a reminder of the need for effective marketing and communication when launching Web applications.

Our second contribution is to provide a case study of applied design from both the cartographic and information visualization traditions that can be generalised to contexts where citizen surveys are analysed. To do this effectively we have advocated the use of creative workshops for generating detailed requirements; the use and development of design guidelines at an early stage in the design process; and the application of design principles and influences from disciplines traditionally outside of geographic information science – to create fluid interfaces and to develop narrative. The study has highlighted the design tensions that can arise when drawing these traditions together (e.g., cross-filtering and avoiding analytical dead-ends) and shown how complex some of these decisions become, but suggests that with robust establishment of requirements, these tensions can be balanced. These approaches and some of the solutions are transferable to other contexts. We justified the use of LCC data analysts (particularly well informed citizens of Leicestershire) in the requirements stage due to our need to "*push out the boat*" as asking citizens what they wanted us to design was unlikely to result in innovation. We appear to have met some of their needs, but the lack of active use of the software by other citizens of Leicestershire means that we are unable to evaluate the tool in its wider context effectively to see whether designs developed for those who know the data and participate in the requirements activity (including the visualization awareness workshop) are more broadly relevant and can be introduced to a wider group using the techniques that we implemented. In short, as an experiment in design for the local authority we would claim some success. As an experiment in design for the citizens of Leicestershire the jury is very much out. We have subsequently used deliberate means of promoting creative thinking in requirements elicitation exercises (Goodwin *et al.* 2013), and it would be interesting and informative to involve citizens in this kind of activity through which unknown requirements are established.

Our third contribution has been to document experiences and reaction that we hope will be helpful to others designing similar tools. Our non-intrusive approach to usage logging and visual log analysis enabled us to make some limited assessment of the effects and suitability of design choices without interfering with user behaviour. It has allowed us to use geographic lookup of IP addresses to separate uses into distinct broad groups – especially useful when exploring geographically relevant data such as those in the Place Survey. From the log analysis we show that the different ways of constructing narrative have been used and can conclude that an optional guided tutorial embedded in a tool can influence use of the tool itself and that separating 'advanced' analytic functionality, while making the guided introduction into an analytic tool's use easier, is likely to limit advanced analysis.

The study as a whole raises some interesting questions about incorporating some of the newer and more advanced approaches to information visualization into services for the general public. To what extent should general users of such services be presented only with the familiar (such as conventional choropleth mapping or Google Maps style 'push pin' symbolisation) even when this contradicts established good practice? Is the goal of incorporating flexible analytic capability, such as cross-filtering, too ambitious for a general audience, or is it a necessary part of increasing general graphical and analytic literacy? At the very least we have argued here that piloting more graphically sophisticated analysis tools for the general public in collaboration with data owners and monitoring their use is one way of beginning to answer these questions and offer some guidelines and reflection that may help others answer them more fully.

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