Examining the Contribution of Critical Visualisation to Information Security

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ABSTRACT

This paper examines the use of visualisations in the field of information security and in particular focuses on the practice of information security risk assessment. We examine the current roles of information security visualisations and place these roles in the wider information visualisation discourse. We present an analytic lens which divides visualisations into three categories: journalistic, scientific and critical visualisations. We then present a case study that uses these three categories of visualisations to further support information security practice.

Two significant results emerge from this case study: (1) visualisations that promote critical thinking and reflection (a form of critical visualisation) support the multi-stakeholder nature of risk assessment and (2) a preparatory stage in risk assessment is sometimes needed by service designers in order to establish the service design before conducting a formal risk assessment.

The reader is invited to explore the images in the digital version of this paper where they can zoom in to particular aspects of the images and view the images in colour.

CCS Concepts

•**Human-centered computing** → **Visualization theory, concepts and paradigms;** *Participatory design; Computer supported cooperative work;* Graphical user interfaces; •**Security and privacy** → *Social aspects of security and privacy;*

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Keywords

Visualisation, risk assessment, critical discourse, cultural studies, humanities, design, design research methods.

1. INTRODUCTION

We are witnessing an explosion in the use of data visualisation tools, and many contemporary information security research projects include a visualisation component, often as a means to accessibly communicate scientific results. Yet, visualisation offers more than accessible communication of scientific results. When considered as a process of framing, gathering, selecting, arraying and presenting data, visualisations also offer their viewers the possibility of both comprehending scientific facts and exploring the social and cultural context in which the scientific facts are situated. Whilst information security visualisations often focus on the *communication* of the scientific, there are also examples of visualisations providing a means of scientific *exploration*. However, information security visualisations rarely communicate the *circumstances* in which the represented scientific facts were produced. Facts are embedded within a particular cultural and social context and it is this situatedness that brings with it multiple perspectives and value systems. Drawing from a humanities discourse, this paper contends that understanding the social and cultural situatedness of information security facts and figures is fundamental to risk assessment and our understanding of risk as a socially-constructed phenomenon [1]. Human Computer Interaction scholar Paul Dourish highlights that risks are emergent from the meeting in time and space of people, information and activities and therefore, we would argue, the depicting the situatedness of information security risk is vital:

> Indeed, it may be inherently implausible for typical users to specify, in advance of particular circumstances, what their security needs might be; those needs arise only as a result of specific encounters between people, information, and activities [12].

The socially learned aspect of risk is further highlighted by Douglas and Wildavsky [10]:

> Common values lead to common fears (and by implication, to a common agreement not to fear other things) [...] In the meantime, acting in the present to ward off future dangers, each social arrangement elevates some risks to a high peak and depresses others to below sight. This cultural bias is integral to social organisation.

It is therefore important to be able to examine the cultural and social context in which risk facts are presented and, as our case study shows, visualisation offers a valuable tool to support such examination.

Visualisations help us to move between different paradigms of knowledge-production ranging from the positivist (where scientific knowledge is assumed to be the only valid form) to the hermeneutic (allowing older, situated and interpretive forms of knowledge). The concept of paradigms and the notion that there are different, rival paradigms of knowledge production is adapted from a post-empiricist account of science initiated by Thomas Kuhn [24], who endeavoured to explain how prevailing conventions of "normal science" are periodically challenged by "extraordinary science," when rival paradigms are proposed. An overview of developments in post-empiricist philosophy and science by Bernstein [2] argues that Kuhn's position is better understood not as a relativist position but as the recovery of a hermeneutic method, which does not abandon the appeal to evidence or strength of claims to truth, but situates such claims with its "thematic emphasis on understanding and interpretation" (p.30).

In terms of visualisation practice, a positivist approach seeks to further a global standard of representation based on a universal model of cognition. In professional design discourse, this trajectory commonly links back to the influence of Otto Neurath's pictorial statistics, and his motto that "words divide, pictures unite" [30]. A hermeneutic approach, on the other hand, acknowledges the situatedness of the knowledge producer and visualisation designer, and their respective ontologies and systems of knowledge production. Johanna Drucker's work has been particularly influential in challenging positivism in information design and interactive design discourse, drawing instead from the humanities and digital humanities. A strenuous critical tradition can be found in geography and cartography, where visualisation (as maps) has a rich history: for instance, Neurath's motto is challenged by a critical position articulated by J.B. Harley [19], who, after J.H. Parry, saw maps as "slippery witnesses" (p.30). Several recent works, including mapping and Geographic Information System (GIS) texts by Denis Wood [43] and Jeremy Crampton [9] help to develop a critical approach to cartography; a field of study and practice that is emerging amid amateur, open-source and experimental practices.

Broadly speaking, visualisation is produced in one of three contexts of practice: journalistic, scientific and critical [18], where journalistic visualisation communicates a finding or a conclusion as clearly and succinctly as possible; scientific visualisation presents the viewer with a scientific pattern or data and invites the viewer to explore the output of the science; and critical visualisation where predominantly artistic techniques are used to invite the viewer to critique the underpinning assumptions, paradigms and philosophy of the narrative communicated via visualisation. Of the three, critical visualisation is the most clearly aligned with a hermeneutic approach, in that it seeks to draw attention to the sociology of scientific knowledge, i.e., in what circumstances it was produced (Fig. 1). [1]

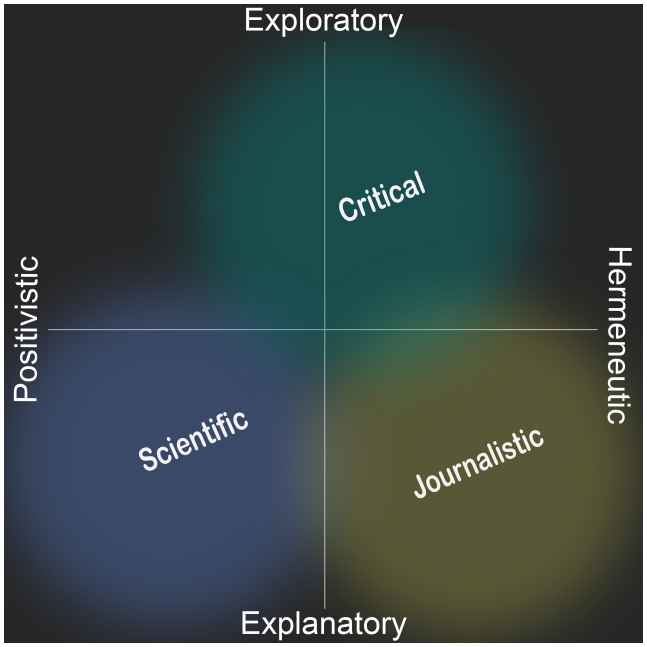

Figure 1: The mobile categories of visualisation.

1.1 Examples of the three types of visualisation

Fig. 2 shows examples of scientific visualisations, detailing graph representations of IT infrastructure elements and access control patterns, clarifying and detailing in an analytical manner the novel descriptions in the respective articles. By contrast, Fig. 3 uses a journalistic visualisations to communicate the results of scientific exploration; namely the groups of security incidents by attack types and attacked industry sectors. These figures represent types of visualisation that are typically used as part of information security practice and research.

Fig. 5 uses a critical visualisation to invite the viewer to compare public risk perception with the scientific quantification of bio-hazard risks. In this visualisation the culturally and socially situated nature of risk perception is compared with the scientific analysis of the risk. This visualisation was produced as a carpet and viewers were invited to stand on the visualisation and physically compare their risk position with the ones presented in the carpet 4. Such critique is not typically invited by the more traditional scientific and journalistic visualisations.

This paper will outline the prevailing discourse on information visualisation, place information security visualisation within that discourse and then present a case study

[1] In Hall's original paper [18] the critical visualisation is referred to as artistic, due to the intended audience of that paper (graphic design researchers and educators), but in applying this work to information security, the artistic category of visualisation is more aptly described as critical, as explained in the following section.

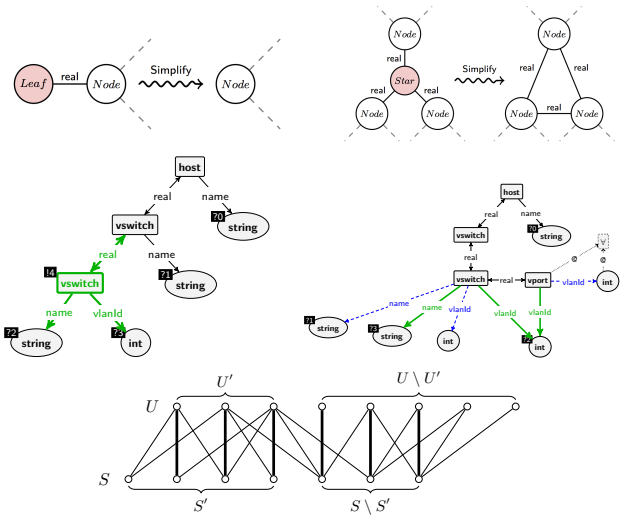

Figure 2: Examples of scientific visualisations. Upper and middle figures taken with permission from [4], bottom figure from [8].

that demonstrates a broader range of information security visualisations. This paper will conclude with a discussion about the potential value of widening the range of information security visualisations that are used in information security practice and research.

2. VISUALISATION LITERATURE

The literature related to information visualisation is vast and we focus in this section on journalistic, scientific and critical visualisations where they occur and on discourses of critical cartography and social semiotics which inform such visualisations. It is important to understand the roles of journalistic, scientific and critical visualisations because in robust scientific visualisation offers tools and techniques that can be used to both evaluate and validate the science. The analytical lens of journalistic, scientific and critical visualisations enable the examination of the scientific process. Journalistic visualisations communicate the robustness of the scientific discovery, scientific visualisations make visible the process of scientific discovery and critical visualisations encourage of the questioning and exploration of the cultural and social perspectives that inform the scientific discovery.

2.1 Journalistic visualisation

A journalistic approach to visualisations is important to information security because this approach seeks to make tangible information security risks and concerns that often seem abstract and remote. The journalistic approach aims to simplify and explain complex data issues, an ethos articulated in Edward Tufte's visual principles of graphical excellence [40]. As the New York Times graphics director Steve Duenes puts it: "it is our job to edit, condense and reduce" [34]. While the art of information design can be traced to William Playfair and in recent decades has been exemplified in the printed work of professional information designers. The advent of internet-based communication has meant that journalistic visualisation is increasingly presented using quite advanced interactive web-based forms that allow the

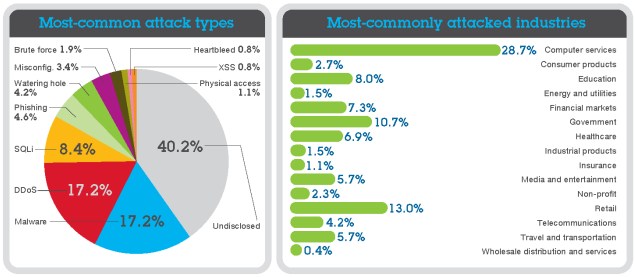

Figure 3: Sampling of 2014 security incidents by attack types and attacked industries (reproduced with permission from [36]).

public to explore data for themselves.

A well-known example of interactive journalistic visualisation is Hans Rosling's Gapminder software which has been used for animating global health data [33]. Gapminder began as an educational tool (to make university students use and understand statistics to acquire a "fact-based" world view), but since it ultimately seeks to inform and transform public opinion, it can be categorized as a journalistic visualisation.

Discussion of formal issues in this category tends to be dominated by the standards codified by authorities like Tufte and Ben Shneiderman. Tufte [40] for instance, argues that information graphics should show the data without distortion, at several levels of detail and present many numbers in a small space (p.13). Shneiderman, focusing on interactive visualisation, argues for visual consistency, informative feedback, a sense that the user is in control, and simple error handling [37].

A journalistic approach to visualisation also places considerable emphasis on narrative, on allowing the graphics to "tell a story" about the data. In their work on narratives Segel and Heer [35] analyse case studies of narrative visualisation from the New York Times, the Financial Times, and Minnesota Public Radio and argue for a balance of author-driven and reader-driven approach to achieve truly interactive narrative visualisations.

An interactive approach to journalistic visualisation is Martin Wattenberg's 'Chimera' search tool which highlights repetition in texts, using graphical "skyscrapers" over the body of the text to visualise repetition. This tool was used to find "clone laws"- legislation pre-written for elected officials by corporations or partisan groups [42]. This type of interactive visualisation offers information security valuable techniques to compare and contrast regulatory environments, policy environments as well as the scientific results from different security incident reports.

2.2 Scientific visualisation

Scientific visualisations enable the exploration of complex data sets and promote dialogue between different scientific communities. Since information security is inherently interdisciplinary, the use of scientific visualisations promotes dialogue about scientific fact through techniques understood to the different communities. Peter Galison has tracked the love-hate relationship with scientific visualisation in physics, noting how it has been associated with intuition, and has raised suspicion in the sciences while also enabling progress

Figure 4: Detail of 'Risk Perception Carpet', 1999-2000, 4x4 m. Image courtesy of LUST, NL.

in quantum mechanics and chaotic systems [17].

Scientific visualisation is generally positioned as a tool of discovery advanced through scientific method. An underlying assumption is that the tool allows unbiased exploration of data. Questions of visual form are generally driven by principles derived from a cognitivist model of artificial intelligence. In this form of visualisation, a universal model of the human brain is posited and the form of the visualisation tested for its appropriateness to the data, usability, and so on [16].

2.3 Critical visualisation

The contention of this paper is that a third category, which we shall call critical visualisation, presents an approach that can facilitate user-led enquiry in information security. An earlier argument for a category of "artistic" visualisation [18] is here adapted specifically for the instrumental goal of advancing visualisation in information security beyond its predominantly technical paradigm. Critical visualisation provides the user with tools through which to enquire about the social and cultural perspective of the facts presented. While it is derived from artistic practices, a critical approach to visualisation is closely aligned to the critical cartography movement that sought to problematise the pervasive post-war discourse on maps that assumed their neutrality. The importance of the role of the arts, and therefore of critical visualisation, has often been underestimated by the scientific community, but from critical cartography we learn that "map art" plays a significant role in shaping the "field of tension" that describes contemporary mapping, GIS and visualisation practices [9].

Examples of critical visualisation that are directly pertinent to information security include 'InfoArcadia,' an exhibition about information graphics, instruction manuals, information landscapes, data clusters, and personal mapping (Fig. 4). The Dutch design agency LUST[2] was commissioned to interpret researcher Paul Slovic's data from 1988 concerning people's perception of risks. The resulting carpet visualised this data as an 'x-y matrix' on which these

[2]http://lust.nl/

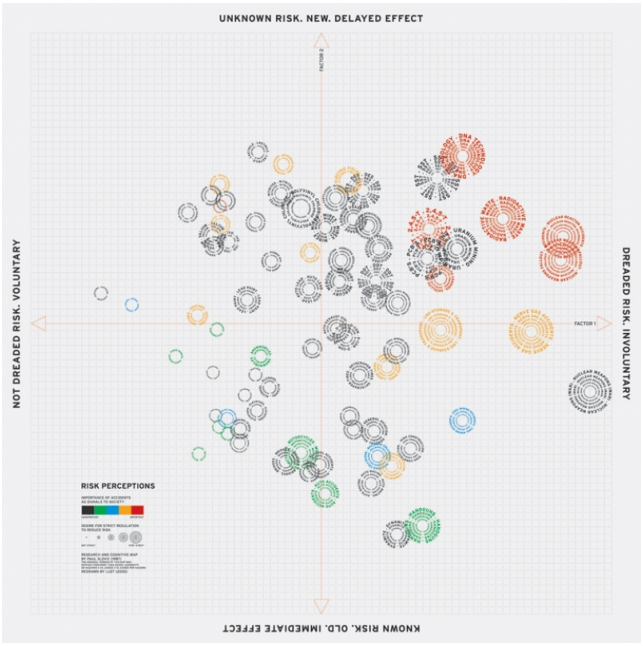

Figure 5: 'Risk Perception Carpet', 1999-2000, 4x4 m. Image courtesy of LUST, NL.

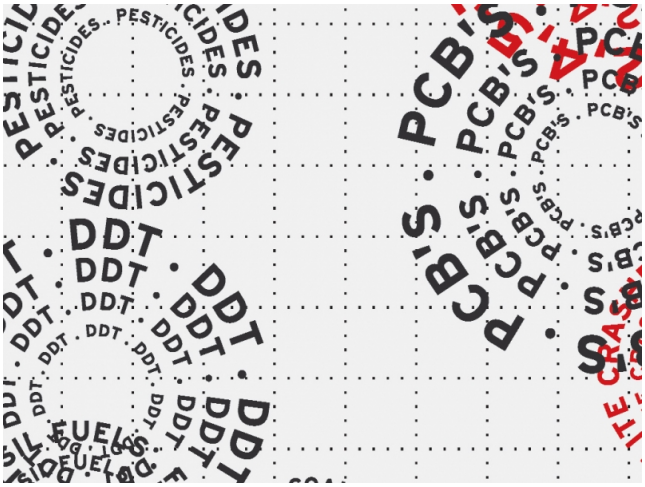

Figure 6: *InfoArcadia* installation shot showing the 'Risk Perception Carpet', 1999-2000, 4x4m. Image courtesy of LUST, NL.

Figure 7: Uta Eisenreich, Network-Teamwork Sociograms, Langmatt School, Zürich [15]. Image courtesy Uta Eisenreich.

'risks' were mapped as 'controllable versus uncontrollable' and 'known risk versus unknown risk', also the desire of people for strict regulation of certain risks, and the importance of certain risks as signals to wider society (Figs. 5, and 6). Importantly, LUST designers stated that 'the visitor would form the third axis (z)', thus completing the design by actively exploring its properties.

Another example of what we are calling critical visualisation, by the artist Uta Eisenreich (Fig. 7), comprises a series of photographs of a social network diagram as created by children at a school in the Netherlands. The children were invited to connect to each other with coloured string, in response to prompts such as which three classmates would they choose to invite to their birthday party. The visualisation depicts a fragile and ephemeral social network, particularly relevant when the connections between nodes are established by users and are based on intangible, contentious and subjectively interpreted concepts such as envy. Precisely the same adjectives could be applied to a visualisation of perceived risk and vulnerability in a social network visualisation depicting information-sharing practices. In this way, Eisenreich's project inherently critiques the presumed objectivity, certainty and permanency of conventional social network diagrams.

As these examples show, critical visualisation has a role that includes bringing to light and experimentally inverting and re-channelling the prevailing assumptions behind the current rhetoric of visualisation. It thereby offers new, alternative modes of representation, much needed if we are to comprehend today's complex information security landscape and propose alternative paradigms. Taking a fresh perspective on the landscape, can bring to our attention the things seen habitually, but not truly observed. The critical is a mode of practice especially suited to exploring the linkages between the technical and experiential and emotional aspects of information security and helping the user to develop a sense of situatedness.

2.4 Journalistic, scientific and critical visualisations in concert

As Fig. 3 illustrates, time and sequencing are themes that appear in security reports and are often represented through the use of charts and timelines. Time is also an important scientific variable in our calculations of risk and impact. The variety of different visual approaches to presenting and describing time in different scientific contexts potentially provides the field of information security with a sense of how it might start to use visualisations to deepen and question our understanding of our field.

Dominant conceptions of time, for example, can be critiqued through visualisations that challenge the Enlightenment convention of depicting time's "progress" as a sequential line marching forward, with the present marking the pinnacle of human achievement. [32]. The challenge of representing temporality is particularly significant when depicting the network map. The authority of the line-and-node diagram found in many network maps implicitly suggests that the network depicted is fixed in time and yet when considering information security risk, understanding risk over a period of time is often fundamental to risk analysis. Visualisations need to reflect this evolution in order for analysts and scientists to derive relevant meaning. As one group of sociologists has noted [22]:

> Most network images do a poor job of representing change in networks, and researchers make do by presenting successive snapshots of the network over time. The problem is fundamental to the media. To effectively display the relational structure of a social network, at least two dimensions are needed to represent proximity, and that leaves no effective space (on a printed page) to represent time.

A simple adaptation of an existing critical approach time[13] might lead us to focus on the representation of time in a high-stakes, high speed information network. For example, a security consultant's perception and understanding of critical time values in a stock trading system might warrant a visualisation that depicts the vulnerability caused by a millisecond delay; the same system might be depicted on a different temporal scale by a managerial colleague responsible for purchasing equipment. In this way the representation of time is relevant to the risk period in each case.

In summary, it is important to uncover the viewpoints at work with risk visualisations in order to understand the perspectives involved in the analysis and conclusions of measures of risk. This requires visualisations that invite the viewer to evaluate risk (scientific visualisations), visualisations that present risk conclusions (journalistic visualisations) and visualisations that invite the viewer to explore the beliefs and values that underpin a risk evaluation (critical visualisation). In this last category, the role of the viewer becomes a more active part of the meaning-making process and is encouraged to contribute to the narrative of the visualisation rather than be the recipient of a pre-determined narrative.

The roots of combining journalistic, scientific and critical visualisations for a more holistic approach to engaging with, communicating and understanding science can be found in the fields of critical cartography and social semiotics.

2.5 Critical Cartography

The field of geography has been influenced by the work of J.B Harley [19], Denis Wood [43], and more recently Jeremy Crampton [9], among others in critical cartography. In these examples of fields of study in situatedness and cartography we can see the scholarly roots of analysing the combination of critical, scientific and story-telling or journalistic techniques to situate facts and figures within cultural, social and historical contexts.

The link between cartography and visualisation is evident in their shared histories. Tufte and cartographic historian Arthur Robinson have both shown that the origins of thematic maps are tightly entwined with cartography, extending back at least to Edmund Halley's map of trade winds [31]. Robinson's seminal study provides plenty of historical evidence to support a situated understanding of thematic maps, as projections of particular cultures at particular times and places.

Visualisations can be critiqued in much the same way that maps have been to reveal their situatedness in time and history. The map historian J.B. Harley showed that we must look for a map's "silences" to reveal their obscured agendas - maps "exert a social influence through their omissions as much as by the features they depict and emphasize" [19]. Similarly, today's network maps and visualisations of suspicious internet activity reveal their territorial imperatives through what is left out. Maps of the internet coming from computer research labs in the late 1990's, for example, tend to perpetuate a separation of "cyberspace" from real space by visualising network activity on a blank background. Contemporary visualisations of network activity use the same formal separation of the informational from the social, which has arguably blinded analysts to the impact of social networks and real space activity on security.

Maps not only represent physical and digital topographies but also emotional topographies. For example, a diagram of "subject matter experts" produced by management consultant and network analyst Valdis Krebs in 2008 [23] reveals its own imperatives through what is *not* shown. Such a visualisation is meant to help us identify the fragile nodes in a company's knowledge domain, the visualisation depicts people as boxes connected by lines: they are connected if one goes to the other for expertise, and those with many arrows pointing to them are the "subject matter experts" sought out often for advice. In Krebs' diagram are assumptions about the rate of transfer of knowledge around a network and the organisational culture. A culture in which people share knowledge freely in pursuit of a shared goal will lessen the impact of a subject matter expert departing the organisation, whereas an environment in which knowledge is coveted as a form of power will be made potentially far more vulnerable by the departure of a subject-matter expert. Ultimately, a map of the mood of the network may be more useful than Krebs' abstracted top-down view.

2.6 Social Semiotics

Further light can be shed on the field of security visualisation by considering recent discourse in the area of social semiotics, a field closely aligned with critical cartography. Whereas a basic application of sign-systems theory is evident in security visualisation practices, the more recent social semiotic argument that signs and symbols cannot be understood in isolation but need to be studied in light of the social dimensions that are intrinsic to their function [21], has yet to permeate security discourse. For example, we might consider the fairly commonplace citation in security visualisation texts of the visual principles of Jacques Bertin, whose comprehensive semiology of maps and diagrams endeavours to establish a universal sign-system that governs the meaningful use of graphic forms in diagrams and maps [3]. Drawing from Bertin, for example, one recent security visualisation text [29] states that "the human visual system has its own rules" and that this knowledge can be translated into "rules for displaying information". By contrast, a social semiotic position contests that graphic forms cannot be meaningfully studied outside of their social contexts; a 2011 study of the boundary line used in maps and visualisations, for example, considers how these seemingly simple and authoritative graphic forms have a complex, uncertain and ambiguous nature when considered as concrete spatial practices. The social semiotic account notes that Bertin "does not subject the graphic figure of the line to any form of critical investigation" [5].In another example, the physical line used to depict the UK border in the carpet at Stansted Airport, when scrutinised in a larger political and cultural context, is a complex and contested figure. Similarly, the lines used to depict potential attack paths in a security visualisation become considerably more rich and meaningful when the lines they represent are studied in their actual, social context.

3. VISUALISATIONS IN INFORMATION SECURITY- THE CONTRIBUTION OF CRITICAL VISUALISATION

Information security has not been left untouched by the discussions and developments in data visualisation. Information security "voices" notably James Lynne (Lead technologist, Sophos) and projects such as Cybaware and Skyrails illustrate how data visualisation is regarded as an important means of communicating information security facts and concepts. However, the data visualisation movement of which information security is a part typically opens no critical window on the medium being used to convey the facts and this potentially hampers information security practice, as the situatedness of the data is often lost. It might be argued that to highlight the assumptions, cultural values and generalisations in a visual mode of representation would dilute and confuse the security message. However, for security topics, the cultural is often fundamental. James Lyne's TED talk in 2012 shows us very clearly that a cultural understanding of hackers and malware developers is fundamental to the work that companies such as Sophos do and yet, interestingly, the visual presentation does not use visualisations that encourage enquiry, discussion, or critical evaluation.

With a view to developing tools and capabilities that support the presentation of security facts and figures and promote enquiry, we will now analyse the nature of visualisations in contemporary information security reports and papers.

Information security is a complex, multi-dimensional topic that has always combined the experiential with the scientific in a type of rich, multi-threaded tapestry. Why humans disclose what they disclose in the way that they disclose it, and manage information in the way that they manage it, has as much to do with internal context (how an individual feels

about the interaction and the data), as it has to do with the external context and the terms of the exchange [11], and any meaning we can derive from such actions is situated with a particular combination of internal, external and emergent contexts.

The multi-dimensionality of security problems can be seen clearly in the latest security vulnerability reports [28, 39, 41, 36]. These reports highlight the complexity of the security vulnerability landscape, with vulnerabilities ranging from software flaws that allow for SQL injection attacks, Cross Site Scripting on the server side, but also third-party plug-ins like Java, Adobe Flash on the client side, as well as weak operational procedures that do not patch and correct these flaws as part of software installation and management as practised within an organisation. As an indication for the latter, it is observed that still to a large extent breaches are detected by external entities, not the organisations themselves, as well as a general unpreparedness to react to and handle such breaches (the Mandiant report [28] calls them "inevitable breaches", as there is "no such thing as perfect security"). Reports in the last six months also show an increase in mobile malware, more sophisticated techniques like RAM scraping (i.e., accessing and harvesting in memory data) and also talk about social engineering with the focus on phishing activities. One more observation is the increase of "designer vulnerabilities" [36], i.e., vulnerabilities with a branded logo, website and catchy name like 'Heartbleed', 'Shellshock', and 'POODLE'. These often are vulnerabilities in long-held foundational frameworks used by a large part of existing websites. But still, besides the huge publicity of data breaches, the use of weak passwords is a major issue and entry point for attacks.

There are a number of dominant narratives across these reports:

- Diversity of organisations that have been affected by information security breaches,
- Persistence of certain software flaws,
- Cultivation of attack surfaces across platforms that previously had not been successfully targeted by attackers, and
- Significance of poor security practices.

However, the visualisations in these reports do not reflect these dominant narratives. Instead the narrative told by the visualisations is mostly that of the comparison between the volumes of particular types of attack, year on year. These conclusions are presented in journalistic form as the results of scientific enquiry. The types of visualisation that are used to display these results are from the scientific tradition: bar charts or other forms of chart that enable volume comparison, timelines, and process flows dominate the presentation. Only one report [36] includes a pointer to online versions of visualisations allowing further interactive journalistic exploration. [3]

The reports are mostly text-heavy, though the Trustwave report [39] embeds this into strongly coloured illustrative graphics. They convey additional narratives that are related to the social and organisational aspects of the current security vulnerability landscape, e.g., all reports communicate a narrative of poor security practices leading to vulnerabilities, and some try to illustrate these narratives with visualisations of the involved components and a timeline.

However, organisationally oriented narratives are difficult to present in a simple journalistic form and, when rooted in the scientific tradition, struggle to represent the nuances of organisationally defined narratives.

One well-known report published in 2013 [27] presents very extensively a long-standing attack and contains some visualisations that attempt to explain how attacks take place, the lifecycle of a persistent and thorough attack, and the context in which attacks take place. These are visualisations that follow journalistic rather than scientific traditions and yet the narrative is highly simplistic and does not convey the social sophistication or complexity of these attacks.

Only one report [41] starts to ask some critical questions about the available data and the conclusions to draw from them for the root causes of data breaches, but still mostly, across the reports reviewed, the user is not invited to question or evaluate the material presented in the reports. The visualisations are used to re-enforce and augment the credibility of the data that is presented in the report rather than to invite engagement and allow for a range of perspectives. The images that are used and the construction of the visualisations are all designed to communicate strength in the scientific results and yet these reports leave many questions unanswered, including:

- How is the security of SMEs evaluated?
- Why do poor security practices persist?
- Why are trusted third parties not more rigorously vetted?
- What variables are collected in the scientific process, and why?
- Were the same methods used for collection in previous years as were used in later years?

Excluding such questions reduces the possibility for users to situate the visualisations, explore the value of the scientific conclusions and removes the possibility for the inclusion of the user perspective. In order to develop visualisations that do promote viewer engagement and encourage debate and critique, we must look to the field of visualisation and explore the different techniques that are available.

The presentation of the narratives in the report contrasts heavily with the importance of the socio-cultural factors that are used in risk analysis. For example, James Lyne's verbal delivery places an emphasis upon the fundamentally situated nature of security vulnerabilities and attacks. This might be construed as a journalistic tactic to make abstract domains intelligible for non-technical audiences, however Lyne's emphasis upon socio-cultural factors is grounded in a deep understanding of the importance of situating information security facts and figures in their full social and organisational contexts. Lyne's stories of hacking and malware manifest an expert interweaving of the social, organisational and technical dimensions of context, which in turn suggests that the act of unifying them in this way, is potentially a rewarding (and equally scientific) route for security visualisations to explore.

[3] An interactive version of the journalistic visualisation shown in Fig. 3 allowing for further exploration of the data is available at http://www-03.ibm.com/security/xforce/xfisi

It could therefore be argued that for these visualisations to mature, an improved cross-fertilisation between the three contexts of visualisation practice is required. The journalistic practice of making data accessible and legible has much to teach the sciences; and the novel forms and critiques of more creative or exploratory representations can inform, question, and reinvigorate the scientific and journalistic types of visualisation.

4. IPTV: CASE STUDY

This section outlines a risk assessment case study that used journalistic, scientific and critical visualisations in the assessment process. The focus of the case study was a Small to Medium Enterprise (SME) that specialises in the delivery of micro-payments services to small businesses and households. The risk assessment process was used with the SME to plan the design of a micro-payment service to be delivered using Internet-Protocol TV (IPTV) in order to enable low income families to make payments and manage their money using the television as the interface.

4.1 Service background

IPTV has a wide user-community demographic, and the planned service is particularly aimed at users without access to or distrustful of computers and other smart devices. The target user community also contains wildly fluctuating levels of digital and educational literacy. For a variety of reasons these users may be inclined to either withhold or share their personal information and data at different times and under different pressures, pressures that threaten to digitally exclude them from the wider community. In addition, withholding behaviour reduces the likelihood of compliance with the service security requirements. In their use of a service such as IPTV, these users may be extremely vulnerable to abuse of the system, perhaps carried out by other members of the community or from their own carers and family.

Gathering data as part of the risk assessment process is strewn with difficulties due to the enhanced sensitivities of these situations and the complexities of the social arrangements around them. This difficulty is specifically compounded in the case of IPTV, where a full technical specification of the service has not yet been reached (tests being confined to small viability trials, at the time of writing).

4.2 Overview of the method

In the case study we visited the SME five times over a twelve-month period (Table 1). Initial data was gathered and a baseline risk assessment was carried out in order to establish which controls had been designed into the service, and where gaps in these controls still existed. The baseline risk assessment was primarily aimed at modelling the service from the perspective of the service's technological infrastructure, and did not make reference to the perspectives of the target user communities, or to any of the social practices that could potentially be used to protect data in the everyday course of events. In order to derive this type of socially determined data, an initial briefing meeting was held with management to establish the prime focus of the service and to ascertain the nature of its relation towards future users. Four workshops followed, attended by a core of three participants with others joining at different times.

4.3 Use of visualisations

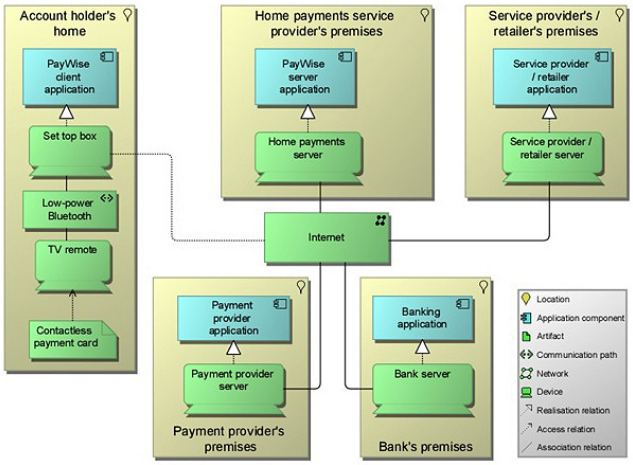

Figure 8: Formal graphical modelling of the infrastructure of the IPTV case study. This employs the*ArchiMate* Open Group risk taxonomy.

The initial baseline assessment of this prospective service led to it being formally modelled with existing enterprise architecture analysis tools (Fig. 8). This successfully conveyed the results of the baseline assessment in so far as it represents the service as a stable, purely technological service, with clearly defined components. However, adopting the perspective described in the discussion of critical cartography (and, by extension, critical visualisation) above, it becomes apparent that such a visualisation promotes the sense that the service is clearly defined at all times, and that all the components are known, which is not always the case. It was noticeable that the case study participants (the service providers) did not recognise this visualisation when it was subsequently presented at the management briefing. This lack of recognition was due to the type of language that was used, which maintained the technological and structural depiction of the service. In particular, the visualisations are devoid of any meaningful representation of mutual human engagement, a fact which is at odds with a service that is fundamentally based on the social networks that are already in place in the communities for which the service was intended.

In order to include actors in the service depiction, a hybrid journalistic-scientific visualisation was produced and is shown in Fig. 9. This attempts something akin to a journalistic simplification, establishing a narrative by positioning stick-man type actors within the diagram. This visualisation is journalistic in the sense that it presents the connections between the technological and human elements as derived from the baseline analysis. This is also a scientific visualisation in the sense that it is designed to function as an expression of formal (logic based) graphical modelling, and because it encourages the viewer to begin to explore the connections between components, and possibly to derive patterns of socially based information sharing or protection practices.

4.4 The problem and the response

During the course of the case study several problems oc-

Management Briefing	Participatory Diagramming	Rich Picturing	Rich Picturing (*LEGO* 1)	Rich Picturing (*LEGO* 2)
AM (male)	AM	AM	AM	AM
WG (male)				
	LH (female)	LH	LH	LH
	AI (female)	AI	AI	AI
	SP (female)			
			NK (female/CEO)	

Table 1: Participation over time. Investigators numbered between two and four at any one time, depending on the focus of enquiry and the expert input required.

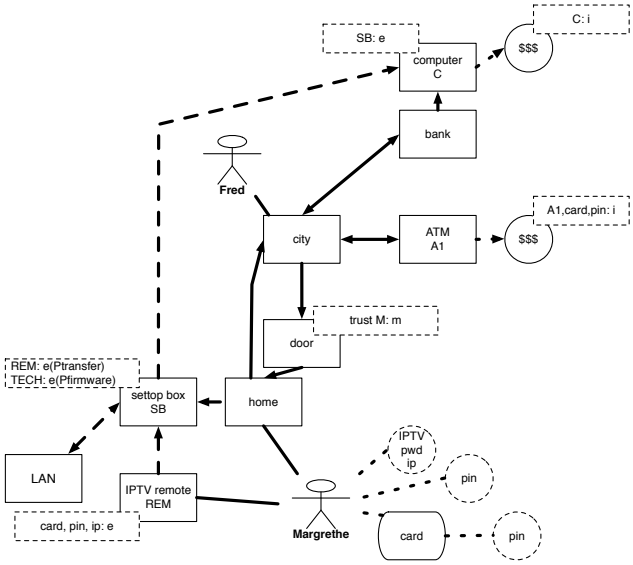

Figure 9: Network model of the IPTV case study.

curred when using standard risk assessment methods:

- The language used by traditional information security risk assessment was unfamiliar to the service providers.
- The standard risk assessment methods required a single asset model which the service providers could not produce whilst the service design was in flux.
- The service providers placed a heavy focus on the social and cultural aspects of attack and defence which are not articulated well in standard risk assessment methods.

Modelling that enabled participants to collaboratively create a representation of the service and to discuss the risks as the representation evolved was demonstrated to be a useful means of overcoming these problems. After a number of approaches were tested in the case study (as seen in Table 1), *LEGO* finally emerged as 'an appropriate technology' for communicating information about how the service providers see their own service design [6]. This strategic use of mixed methods was founded by Robert Chambers, describing it as:

> A growing family of approaches, methods, attitudes, and behaviours to enable and empower people to share, analyse, and enhance their knowledge of life and conditions, and to plan, act, monitor and evaluate.

Using *LEGO* the service designers were able to co-construct a physical model of the service, discussing its attributes and agreeing its form as they did so. *LEGO* is an excellent example of a participatory research technique shown to access 'hard-to-reach' socio-technical data, and this data is represented through jointly or co-constructed physical models in this instance. These models are rich in a highly project-specific symbolic imagery that is closely attuned to IPTV user demographics, a 'future community-of-use' [14].

Table 1 shows the participants' involvement over these sessions and the type of activities conducted. A briefing with management established the focus of the service, and 4 workshops using critical visualisation methods followed. The workshops were as follows:

1. Participatory Diagramming: four participants drew the service from the perspective of their own responsibilities (housing regeneration, micro-loans, and fuel-poverty) to generate a model of core values, services and stakeholders.

2. Rich Picturing: physical avatars were used to overlay an infrastructural data-flow diagram of the service redrawn by hand to a large scale; this produced an object/drawing matrix of the service infrastructure, where concentric rings showed the different types of relations that exist between actors, where different qualities of trust and obligation are present (contractual relationships, partnerships, collaborations, and underwriting, for example).

3. Rich Picturing (*LEGO* 1): next, a specially assembled *LEGO* kit was provided to the group. Participants were asked to model central actors using the colours and language of the traditional risk modelling tool used in the baseline risk assessment. The following representations were therefore used: technological consumables (yellow bricks), infrastructure (green), data (blue), and locations (pink tiles). The weighting and positioning of elements was generally agreed upon, and accompanied by thoughtful and insightful discussions. Actor perspectives were taken from the model, suggesting a solution for unintended consequences of alerts, a new cross-organisational problem-solving role (a fire-fighter standing on a blue and orange brick tower). Verbal prompts to build were based upon the *Archimate* representations, and from their own earlier statements at the briefing (Fig. 10).

4. Rich Picturing (*LEGO* 2): a further *LEGO* session, with three of the original participants, readdressed their model; a new brick colour was introduced in case the

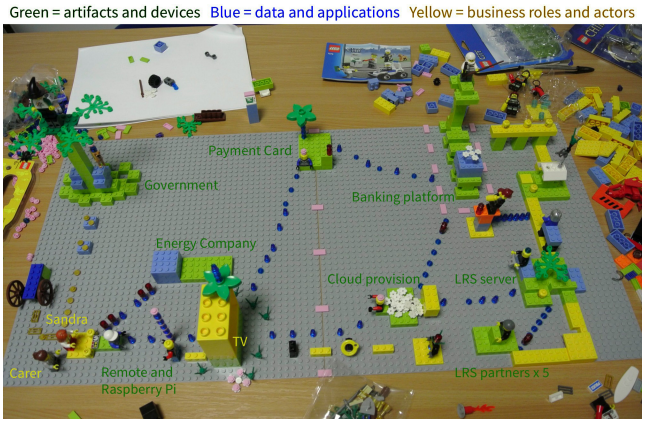

Figure 10: Rich Picturing (*LEGO* 1): a qualitative shared modelling of the IPTV case study, where the service designer's wrestled with difficulties created by unintended consequences of alerts.

Figure 11: Rich Picturing (*LEGO* 1): the model can then viewed from the perspective of different actors, and here the client has a carer at her right shoulder, and a looming energy demand to one side of the large TV and other technological apparatus in front of her.

participants should wish to add technical support measures such as encryption to vulnerable points of the system (darker pink) (Fig. 11).

4.5 The role of critical visualisations

As it became clear that traditional risk assessment methods have limitations, arguably due to a dominant paradigm that insists on depicting mathematical certainties, collaborative modelling methods were also used. This began the process of visualising the service design in more progressive and creative ways. *ArchiMate* was used to feed representations back to the SME team, with the aim of stimulating fresh discussions and improved visualisations of the social aspects of risk that eluded the more traditional visualisations. This new approach was with particular reference to any unintended social consequences (and possible interventions) that could result from "alerts" triggered by clients over-spending in particular. The detailed examination of this scenario led to a keener understanding of the social and organisational risks more generally. The insights that were gained threw light upon the values and alignments that go to make up the essential identity of the project, and which give it its essential character as a business proposition, and how this could be messaged effectively.

The *Architect* tool, an extension of the Open Group's taxonomy and the *ArchiMate* core language, is used here as a springboard for building constructions that stand as agreed metaphors (or abstractions) for infrastructure [25]. By articulating categories of objects to work with the framework is suitable for participatory research aimed at bridging the gaps between different modes of abstraction: inductive research with qualitative data on the one hand, and technical descriptions of infrastructure on the other. The Open Group acknowledges the pragmatic possibility of different approaches being taken to the use of the taxonomy:

> If pure qualitative values are used (i.e., values that don't reference a quantitative range or distribution), then *the taxonomy may be used as a structural reference* rather than a framework for calculation [38, p. 8, our emphasis].

The structural references provided by the taxonomy and by the graphical representations of the infrastructure, proved to be invaluable as a means of integrating different user perspectives into one over-arching visualisation of IPTV. The qualitative or organisation-centric view of IPTV that was gained from these sessions was enhanced by developing upon these structural references, at times exceeding upon them in ways that were surprising and potentially useful for restructuring the design of the service. At the conclusion of the first session with *LEGO* the participants commented on the process of critical visualisation:

> AM: it makes it so graphic...
> NK: it's very unusual for me to be able to sit and do something like that, because it's, you know, everything's up here [finger taps head], it's very healthy for us, I definitely think we should get our own *LEGO* kit... thing's are captured in 3d.

4.6 Combining visualisation types

Running in parallel with this participatory research strand, was an endeavour to re-work the IPTV scientific visualisations, using the insights gained from examining the proposed service in its qualitative details. This graphical task was undertaken using a prevalent scientific visual format, attack trees (Fig. 12). Attack trees are an iconic scientific visualisation as they present the results of scientific evaluation and invite the viewer to explore the attack tree to generate attack patterns using a rigorous scientific process. Although it was clearly possible to add more technical and other information about possible attacker-defender steps to the tree, from an operational perspective the increasing complexity of the trees stands in the way of immediate comprehension and accessibility to experts and non-experts alike.

There are a number of journalistic techniques that can be used to combat this overwhelming complexity. One is for the user to order the paths, ranking them in different ways, according to the difficulty and cost of individual attack-steps towards a central goal, which is the assumed aim of an at-

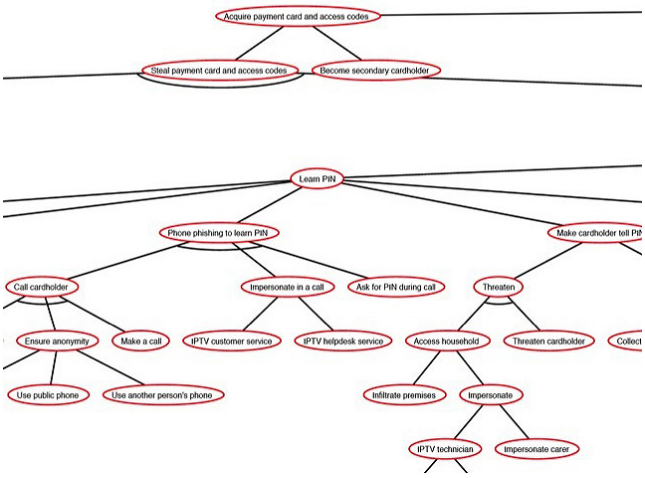

Figure 12: Tree-based modelling of the IPTV case study, with steps moving upwards towards the attacker's goal. Detail of a much larger tree encompassing all of the known and possible attack vectors.

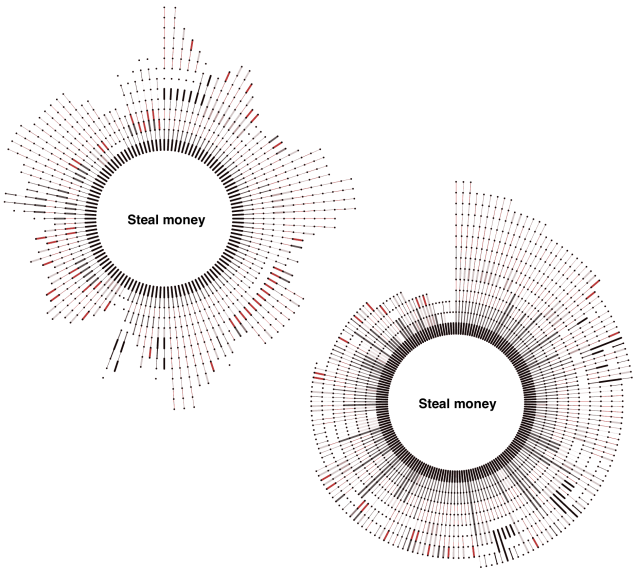

Figure 13: Radially displayed attack trees of the IPTV scenario (image courtesy of LUST, NL).

tacker to 'Steal Money' (Fig. 13).

Another journalistic visualisation step taken to reduce the perceived complexity of the IPTV attack tree, was to remove intermediate nodes and creating traces of basic attack steps out of the tree to allow an understanding of the different possibilities captured in a tree as different sequences of attack steps. This partial collapsing of often-repeated nodes, and the grouping and simplifying of the appearance of some branches (Fig. 14) created a hybrid scientific-journalistic type of visualisation informed by the principles of Tufte and Shneiderman described above. The user is able to interact with the data at the level of detail that seems appropriate. The attack trees, re-arranged radially and ranked by the user of a notional graphical interface according to the number of steps, now reflect the ease and skills required to carry out the attack, including the monetary and resource costs, and other dimensions that may present an accessible 'surface' of opportunity to an attacker (to greater and lesser extents).

By posing fresh observations, novel representations such as *LEGO* and line drawings critique the ability of traditional representations in these areas. Scientific visualisations do not address social practices that support organisational resilience, but a drawing is a suitable medium for extending the exploratory design process that the participants of the case study were engaged with, by representing the zones in which information is shared by key actors (Fig. 15). Analysts modelled the *LEGO* results with their own *LEGO* model, making diagrams and notes relating to key decisions along the way (Fig. 16), or redrawing the *LEGO* model by hand in order to bring out the patterns of socio-technical practice found there, and this can be regarded as a way of rapidly and visually prototyping an interpretation how data can be structured to reveal embedded social practices. If social practices can be identified and studied as a visual unit of analysis, it will be theoretically possible to make visible their impacts upon organisational resilience [20].

These are examples of how different visualisation types can be brought together and hybridised to meet specific aims. In some cases, contrasting types of visualisation can be used by stakeholders of varied backgrounds in order to map out their motivating concerns and to negotiate the management of these interests within a group. For example, in the post-analysis of results of participatory engagement, it has been useful to use a number of methods in combination and in deliberate contrast with each other. Combining the scientific and the critical visualisations can then result in journalistic visualisations that are adequately equipped to communicate the complexities of the risk narrative.

4.7 Reflections

The change in approach towards collaborative modelling methods brought with it the advantage of preserving the earlier insights gained through first briefings and the early formal modelling, and brought about an extremely rich physical representation of the participants' core business values– which was unequivocally claimed as their own.

We adapted the risk assessment process to include an initial exploratory stage using critical visualisation to define the service and understand the risk implications of different service designs. A critical perspective derived from this stage was used at later stages in the risk assessment to calibrate the emerging journalistic and scientific visualisations.This indicates that at least in some situations, a from-the-ground-upwards or 'blank canvas' stage to risk assessment is needed, where critical visualisations and participatory design techniques are used to tease out the focus of the service and the service design characteristics.

The imperatives of journalistic-style accessibility, when combined with scientific representation and critical enquiry upon complex scenarios, has led to remarkably 'rich' representations in this case study, through which our participants have been able to follow their own interests and concerns (Fig. 17). This shows how abstraction can indeed be handled in a critical way, without necessarily impoverishing the social aspects of visualisations, and without depending upon a sparse scientific representational paradigm to ensure credibility and rigour. Indeed, the enriched representations

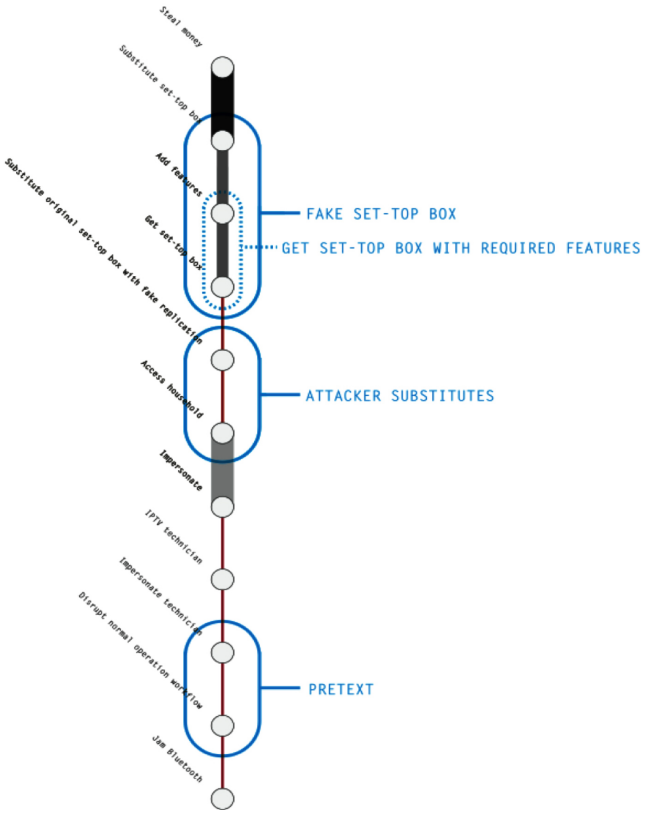

Figure 14: The IPTV attack tree with selected nodes collapsed into a linear path, enabling easier manipulation and comprehension within an interface (image courtesy of LUST, NL).

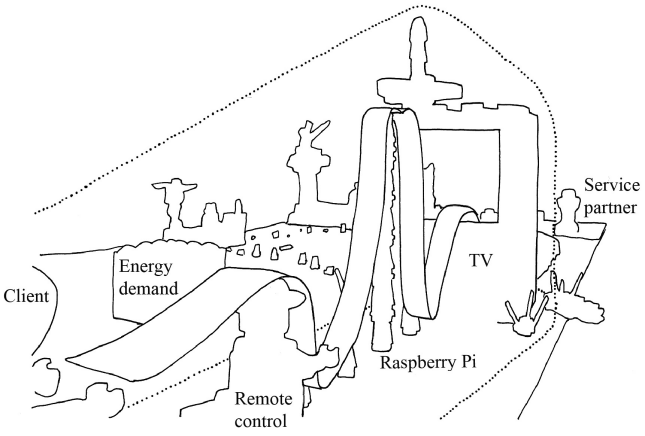

Figure 15: Line drawing of the IPTV co-constructed physical model, made by the authors to show the narrative implied by the group. The client interactions with the technology are shown as a long ribbon extending towards the goal of making a purchase online via their TV. A dotted line represents the extents of this practice at this point in the model (Royal Holloway, London).

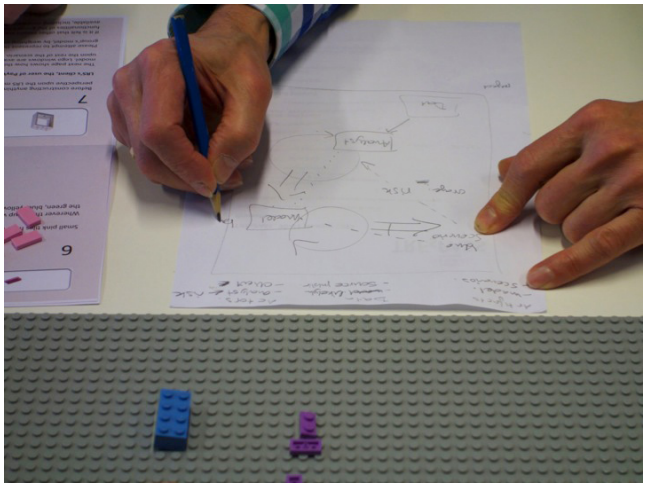

Figure 16: Security practitioner groups, notes and diagrams carried out during modelling.

have been shown to be capable of sustaining a secondary process of critical reflection on the meaning of these models, and have resulted in new analyses of the social practices that sustain a service such as IPTV (Fig. 18). These highly visual forms of thinking and of providing feedback to participants have been useful ways to offer new interpretations, reorganising and clustering together the central values and attitudes that are the greatest 'matters of concern' to a service design where relational services are of the utmost importance [7].

It might be argued that rich qualitative representations have the shortcoming of not being easily understandable outside of the group that created them, and that a qualitative depiction such as this requires a great deal of explanation for it be communicated to people outside of the group, and to convey what each of the elements represents. It is certainly the case that the representation is constructed from an entirely internal viewpoint and that the relations it contains will only make full sense from this interior perspective, which is both an advantage and also a limitation upon such work. This is not to say that key messages cannot be taken from the qualitative representations and be used towards journalistic or scientific ends, as current work analysing them is showing. Security practitioners engaged with our evaluation sessions using this methodology, have indicated that the demand on participant's short-term memory are outweighed by the way in which different types of stakeholders can be brought together by a shared visualisation to share their concerns at an early stage of the design process. The physical modelling enabled the security practitioners to share preconceptions about service design and to make a record of how they have modelled risk and other decisions relating to their analysis, which in turn leads to clearer messaging.

5. CONCLUSION

The *LEGO* and drawing technique described here succeeds in making visible the qualitative dimensions of relations between actors and data in the IPTV scenario. The method has a significant role to play in bringing these issues to the fore, for service designers developing socio-technical services in an increasingly diverse technological and social context.

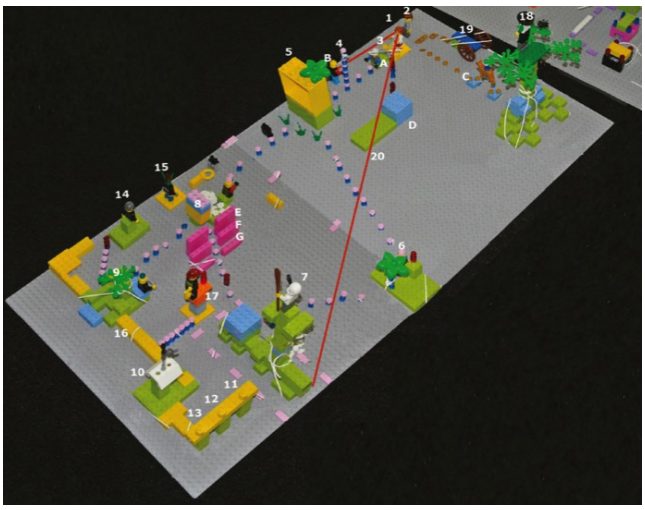

Figure 17: Rich Picturing (*LEGO* 2): a subsequent session returned to the model to reflect on where additional protection will be required, and refining the design of the service to take account of unintended consequences of alerts, some of which could have a deep impact upon the real (and perceived) integrity of the service. Divergent red lines have been added to indicate the client's perspective (Royal Holloway, London).

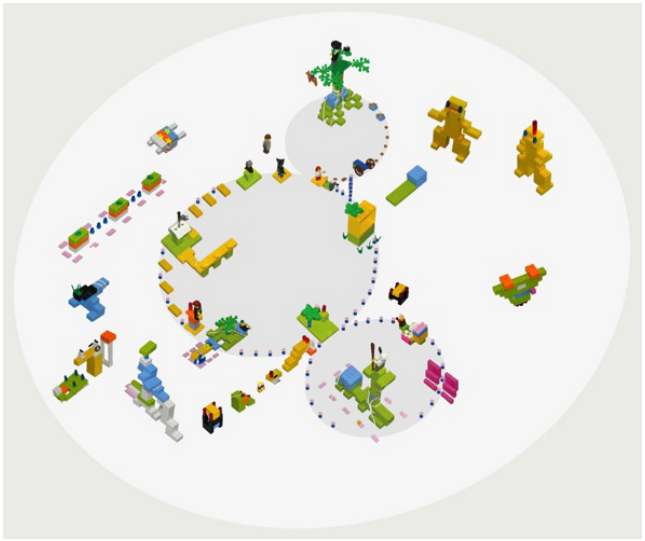

Figure 18: A digital collage of two engagements: Secondary interpretation of the *LEGO* model: TREsPASS security analysts used *LEGO* to identify where in the IPTV scenario data could be usefully extracted and of what kind it would be. At the centre are the initial elements of the service designer's model, while around this are those of the secondary analysts (Royal Holloway, London).

Information security is a complex, multi-dimensional topic that combines the experiential with the scientific. This paper calls for a greater breadth of practices in the development of visualisations in the service of better representing the complexities of information security. For the science of security to progress, it must be able to accommodate alternative paradigms, to revive Kuhn's term again, that challenge existing ones. In the era of 'big data' visualisation, critical visualisation is needed to re-examine the claims of transparency, certainty, and objectivity that are typically embedded in the Cartesian language of the genre. It is this type of language that is used in the information security visualisations presented in the security reports mentioned above (Section 3).

Critical visualisation opens a door through which user or viewer-led enquiry can enter and the discourse related to information security can be widened. In particular, critical visualisations play a key role in the early stages of risk assessment when the service design has yet to be fully defined. It is the insistence on the situatedness of visualisation: the triangular relationship between observer, the phenomenon being observed, and the audience, that enables service designers to reflect on the nature of the service and the implications for security risk. Once this is reinforced, it can be scrutinised as a work of rhetoric, or as Latour would argue, as a "matter of concern" rather than a "matter of fact" [26].

6. ACKNOWLEDGMENTS

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