The Personal Construction of Representation Modality

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ABSTRACT
This paper describes the use of the Repertory Grid Technique as a method of externalizing people's experience of three types of modalities used to represent the same data stream. The primary aim of this study is to test the methodology, so from a repertory grid study that included 12 participants, we focused the analysis presented in this paper on one participants' response. Future work will include examining multiple views in an attempt to explore the extent to which a concept is shared among a group of people as well as adapting the technique to be more efficient and effective at exploring a group of peoples' experience at the same time.

Author Keywords: Data Representation, Repertory Grid Technique, User Experience,

ACM Classification Keywords: H.5.2 [Information Interfaces and Presentation]: User Interfaces - Haptic I/O

INTRODUCTION
The rate of data that we consume today has dramatically increased over the previous few decades. Recent technological developments have enabled us to store ever-increasing amounts of data, while also offering more tools to retrieve and publish this data. Data representations are now an integral part of many aspects of a modern society; from financial and environmental issues to political and sporting performance, we now use data in ways that were never possible before.

Human-data interaction has also evolved in recent years, research fields such as Ambient Displays, Artistic Visualization, Data Art and Casual Visualization have produced artefacts that represent data beyond the visual modality [10, 6]. These tentative steps towards using alternative modalities to represent data have led us to ask the question: How do people construe their experience of interpreting data represented through different modalities? Equally, what are the most appropriate methods to expose these experiences?

In an attempt to answer these questions we present a study that explores people's experience of one data stream represented through different modalities. The method we have chosen to explore these experiences with is the Repertory Grid Technique (RGT). Although HCI researchers have used the RGT for some time, the vast majority of published literature use this technique to explore people's experience of specific technologies such as UI's [4], Search engines [2], Mobile phones [3] and Information systems [7]. This study however, does not focus on technology, but attempts to use the RGT to elicit people's experiences of the concept of representation modality.

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DATA, ARTEFACTS AND MODALITIES
The aim of this study was to create a range of data-driven artefacts that represent one data stream using different modalities, however, the source of the data was not critical to the outcome of the study. In the end we choose to collaborate with Blackrock Castle Observatory and the Irish National Space Centre, Cork, Ireland. These organisations maintain a 32-meter in diameter radio telescope that monitors the real-time Hydrogen levels from deep Space. The rationale for using this source was that we have worked with this data in the past [6] and it has proved to be a reliable and constant stream of data. To acquire the data we utilized the COSM [1] platform. A custom program on the computer attached to the telescope collects the latest data and sends it to an account on COSM. Any computer connected to the Internet can then retrieve this data. For the study we produced three bespoke data-driven artefacts. In designing these objects we purposely did not address any issue related to aesthetics or form, we focused on producing simple objects whose only function was to represent the data through a particular modality. The modalities that we choose to use in the study were haptic, visual and auditory.

Haptic Modality
The artefact that represents the data through the haptic modality utilized vibro-tactile feedback. It consists of a 30cm x 30cm wooden surface. It was a conscious decision to create a relatively large surface area for this piece to allow more than one person to feel the feedback at any one time. Ten 5-volt vibration motors were embedded into the underside of the wood, the speed of these motors is controlled by a microcontroller that is connected wirelessly to a computer. Through a custom program, a constant connection is maintained with the COSM where the latest value retrieved from the telescope is stored. The speeds of the motors increase or decrease depending on the latest reading (high levels cause strong vibration while low levels cause weak vibrations)

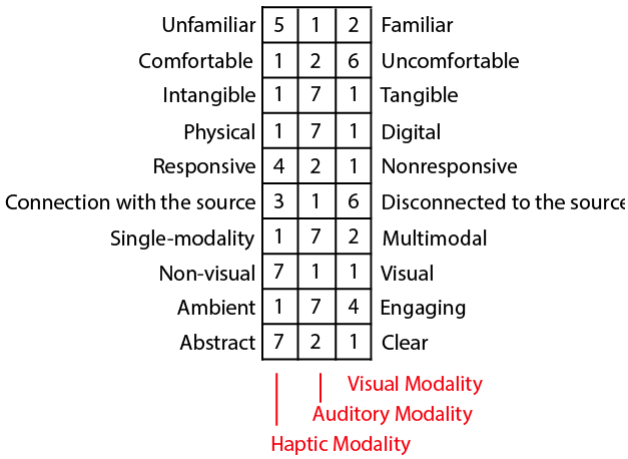

Figure 1. The Repertory Grid of Participant #6.

Visual Modality

The object that represents the data through the visual modality uses a range of colours from green through to red emitted from 4 RGB LED's as its output. The artefact consists of a hollow wooden cube (10cm side) with a 2cm hole in the top face. A microcontroller, which is housed in the interior of the cube, controls the colour of the light being emitted from the LED's. This artefact is also connected wirelessly to the same program that the haptic artefact, which processes the latest reading from the radio telescope at a rate of 60-times per second. When the program captures high values it instructs the microcontroller to emit red light from the LED's. If however the reading is low it instructs the LED's to glow green, values in-between these two extremes cause the LED's to emit the full range of colours in the colour spectrum between red and green (i.e. medium values triggers purple light, medium-high values triggers orange light and so on).

Auditory Modality

This piece consisted of a custom program that dynamically generates a digital sound and plays it through a set of headphones connected to the computer. The frequency that this sonic tone is played represents the latest data values. The headphones are connected to a computer that is running the program that all the artefacts were connected to. When the program reads the latest value from the COSM server it translated this value into the frequency that the sound should be played at. The higher the Hydrogen values the higher the frequency of the tone and visa versa.

RESEARCH METHODOLOGY

The Repertory Grid Technique (RGT) is a methodological extension of George Kelly's Personal Construct Theory (PCT) and is used to systematically elicit the way people construe their experience of objects, people and events [1]. PCT is based on the belief that humans draw their understanding and description of the world they inhabit based upon their own personal experiences and that they distil these into labels (Personal Constructs) that are bipolar dimensions (i.e. sad – happy.) As a method to elicit these personal constructs, the RGT, over time, has been used across many disciplines and has been extended and customised to best fit its particular context of use [11]. However, generally, each variation and adaptation of the RGT still contains three major components: Elements, Constructs and Links.

Elements are the objects, people or events that are under investigation during the study. The participant, as part of the study, may be asked to select these elements themselves, but in most cases the researcher will provide the participant with a set of elements. In our case the elements consisted of three artefacts that represented the same data using different modalities (haptic, visual and auditory).

Constructs are the bipolar descriptions or attributes that the participant assigns to each element. These constructs are usually elicited during an interview that takes place after the participant has been made familiar with the elements used in the study. In our case, the first construct elicited from participant 6 (see fig. 1) was: {*Unfamiliar -Familiar*} this bipolar dimension is used by this participant to describe his experience of the three elements.

Links are methods of connecting the elements to the elicited constructs. The links help to explain how each participant construe each element relative to each construct. This is typically accomplished by rating or ranking the elements against each construct. In our case participant 6 rated the auditory modality as 1 (Likert 1-7) against the construct {*Unfamiliar - Familiar*} with 1 being unfamiliar and 7 being familiar (see fig. 1). This may be interpreted as meaning that the participant believes that representing data through the auditory feels extremely unfamiliar to him. In all, 12 individuals (8 male, 4 female) participated in the study, all of which were final-year digital media students. Their mean age was 23 years (Min = 21, Max = 26). The RGT session took place in a large room with all three artefacts located at separate corners of the room. Each participant took part in an individual session which lasted approximately 40 minutes, it was facilitated by one researcher and was recorded using both video and audio equipment.

Procedure

The 3 components of a typical RGT study (elements, constructs and links) typically have a stage within a RGT session dedicated to them. Here we describe these stages while highlighting further details about our study.

Element Familiarization: This stage is dedicated to making the participant familiar with the elements under investigation in the study. The researcher typically introduces the participant to the elements and allows some time for him/her to interact with them. During our study, following a short introduction and explanation of each artefact, the participant was allowed 15 minutes to engage with all three elements, if they felt they needed more time they were offered as long as they needed. A researcher was present in the room at all times to answer any questions, while also

encouraging the participant to move between all the elements and not to stay with one for too long.

Construct Elicitation: Following the familiarization stage the participant is typically interviewed to elicit their personal constructs. The method we used during this stage was the minimum-context triad form of construct elicitation. From the triad (three) of elements the participant was asked to describe how two elements are similar (convergent pole) but differs from the third (divergent pole) [4]. This continues until the participant is noticeable having difficulties in ascribing new and unique attributes to the elements. In cases where the participant finds it difficult to elicit less than five constructs the researcher would repeat some of the recorded constructs and ask the participant 'why' this attribute is important to them. This method, known as 'laddering', assisted the participant in defining the constructs further and in many cases led to new constructs being elicited. Once it became clear that the participant was no longer eliciting any further unique constructs the researcher moved the session into the next stage. Research has shown that typically the amount of constructs elicited during a RGT session range from 5 – 17 [4]. In the session we report here 10 personal constructs were elicited from the participant as shown in figure 1.

Rating: Typically the third and final stage of a RGT session is dedicated to linking the elicited constructs to the elements. This is done by rating or ranking each element until a full Repertory Grid (RepGrid) is produced. In our study the participant was presented with a printout of an empty grid, which consisted of the bipolar constructs displayed in the rows and the elements in the columns. The participant was asked to rate (likert 1-7) each element against the constructs so that 1 being the convergent pole (left) and 7 being the divergent pole (right). Once this has been completed the participant was asked to read over the grid and confirm that they agreed with it. The output from this stage is the RepGrid (see Fig. 1) it is this grid that is then analysed in the next part of the RGT study.

GRID ANALYSIS AND DISCUSSION

Once the constructs have been elicited and the RepGrid has been produced, it may be then analyzed using a range of quantitative or qualitative methods. Although we had 12 individual RepGrid's to analyse, the work presented here focused on just one grid as shown in figure 1. To analyze this we choose two methods: Cluster Analysis and the Principle Components Analysis (PCA). Cluster analysis uses FOCUS grids to show the highest possible correlation between constructs, this is done by reordering the rows and columns to produce a 'focused grid' that has the constructs that are statically similar placed beside each other. It also builds a dendrogram (tree diagrams) that illustrate the strength of these relationships, as shown in figure 2.

The Principle Components Analysis (PCA) generates a map representation of the data, as shown in figure 3, that allows you to see the relationship between constructs and elements

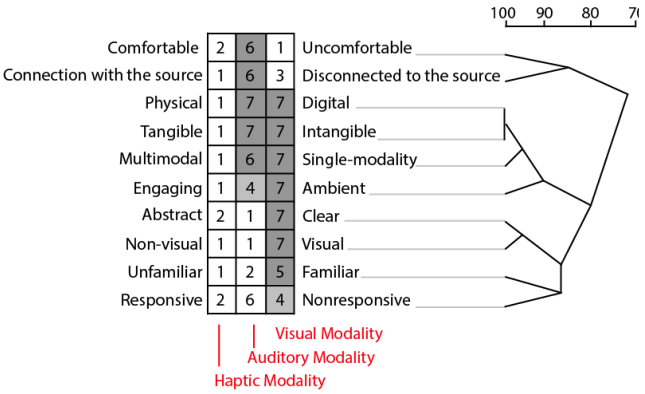

Figure 2. The FOCUSed Grid of Participant #6.

while also showing where clusters occur. Both of these are distance-based methods, as they expose the degrees of correlation between and among constructs and elements by calculating the statistical distance between them.

The analysis we present here is from a RepGrid that was elicited from participant #6 in the study, a 23 year-old male who is a final-year digital-media student. This participant was chosen at random to provide us with a exemplary grid to analyze, future work will examine all of the grids to expose any trends evident across the group. When we examine his FOCUS grid (Fig. 2) and apply a high cut-off point of 90% (i.e. we focused on associations statically higher than 90%) we can see two reasonably strong clusters:

- {Physical/Tangible/Multimodal/Engaging – Digital/Intangible/Single-Modality/Ambient} (90%+)
- {Abstract/Non-visual – Clear/Visual} (95%)

This means that the modalities he describes as " Physical" and "Tangible" have a propensity to be also described as "Multimodal" and "Engaging". Equally, this participant also sees modalities that are "Non-visual" as "Abstract". This may seem to point towards data, represented through visual modalities, being easier to understand than other non-visual modalities. However, we also can interpret from this grid that 'non-visual modalities', that are physical and tangible in nature, engage people more that those that are intangible such as the visual or auditory modality.

We can also see in his grid that he does not distinguish between the construct {Physical-Digital} and {Tangible-Intangible). Although there is nothing surprising about the similarity of these attributes, to distinguish these, we would need to re-interview the participant to further explore why he associates both of these constructs with the same elements, this may led to a redefinition of these constructs or indeed eliciting new set of constructs.

In participant #6's PCA grid (Fig. 3) the first component accounts for 67.3% of the variance and together with the second, 32.7%, it will identify 100% of the variance in the data. This is extremely high but not unexpected as there were only 3 elements used in the study so there was never going to be a large variance in the data. When we examine these two components we can interpret the first (x-axis,

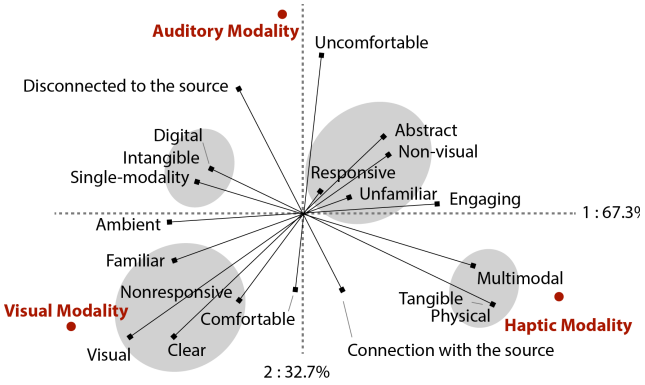

Figure 3: The Principal Component Analysis of Participant #6

67.3%) as being related to the way he engages with the data, either in the periphery (ambient) or within his primary focus (engaging). The other component (y-axis, 32.7%) can be read as relating to how he experiences the data, i.e. whether it was a comfortable or uncomfortable experience, or less so, whether the data was metaphorically linked to the modality or not (i.e. "connected with the source).

We also see in his PCA grid that there are two strong clusters formed close to two of the modalities. Firstly, a dimension of the cluster (Visual/Clear/Familiar/Nonresponsive – Non-visual/Abstract/Unfamiliar/Responsive/) is closely grouped with the visual modality element. Although it is to be expected that statically the construct (Visual) is closest in distance to this element, the other construct (Clear) in this cluster is not so obvious, although it does help to reinforce what emerged from the FOCUS grid. The other cluster (Multimodal/Tangible/Physical – Single-modality/Intangable/Digital) helps to supports a theme that emerged from the FOCUS analysis. We also see that these attributes are clustered closely around the haptic modality, however, the construct (engaging) does not appear in this same cluster but it is closer to the haptic modality than the other two. We may interpret this as the haptic modality offering a level of engagement more than the other two but not some much as to ascribe this property exclusively to this modality.

CONCLUSION AND FUTURE WORK

In this paper we presented the procedure and initial analysis of study that examined the use of the Repertory Grid Technique as a method to explore peoples' experience of different modalities used to represent one data stream. The modalities that were under investigation were haptic, visual and auditory. Although the analysis of this study is at an early stage we believe that we have shown that the RGT is a useful tool to investigate a property such as representation modality. By using this method we highlighted some fundamental themes that emerged when we elicited a participants' experiences of these modalities. We see these highly personal themes as indicators of what might be the important constructs to examine more closely during the comparison of all the RepGrids, which is the next stage of this study. Once this comparison is complete we should be able to see whether these appear as trends across a group of participants. Although we have exposed some insights into an individual participant's experience of the modalities by using the RGT, we also discovered that this method is cognitively demanding for both the researcher and the participant. During the construct elicitation stage, which was the longest and most demanding of all the stages, many of the participants remarked that they found it very difficult to ascribe attributes (constructs) beyond the most obvious ones. The researcher also noted that this stage was very exhausting, as he was aware that he must encourage and assist the participant to elicit their descriptions of the elements but take care to not interfere with the process too much to cause researcher bias. To address this we have already conducted a group RGT study that investigated the same elements from this study, however, unlike this study, the element familiarization and construct elicitation stage was conducted with a group participants together in one room. Next we plan to compare the findings from the next stage of this study with those from the group RGT to examine whether a group study can elicit richer insight while being less demanding for the participants and researcher.

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