Evaluating an animated and static time series map of District Six: A visual and cognitive approach

Nurudien Dawood[1], Siddique Motala[2]
[1] Chief Directorate: National Geospatial Information, Department of Rural Development and Land Reform, Cape Town, South Africa, dawoodn08@gmail.com
[2] Department of Civil Engineering and Surveying, Cape Peninsula University of Technology, Cape Town, South Africa, motalas@cput.ac.za

DOI: http://dx.doi.org/10.4314/sajg.v4i3.1

Abstract

Visualization of spatial information is an important aspect in the representation of map displays. Maps today are visually adapted to a variety of mediums in displaying spatial information temporally and as time series phenomena. GIS technology has incorporated tools for analysing these spatio-temporal trends. However map users are overwhelmed by the amount of information in these map displays and therefore experience cognitive overload. In this study we find that static and animated maps have their respective advantages in the visualization of the map reader by placing participants through a structured set of questions. All these facets exist in the visual and cognitive realm of the map reader. District Six is a unique area that has experienced significant spatial change in the last century, mainly attributed to its political history. This has been depicted in a conventional static and animated time series map representation which has been designed to facilitate the understanding of the spatial change that occurred during this unique period of history. In this paper a methodology has been investigated and implemented in the design of the map, by enhancing the map reader's experience in visualising time series spatial data. We conclude further that visual intention and attention are cognitive facets that collectively strengthen the map reader's ability in learning spatial information.

1. Introduction

1.1 Background

District Six has become an iconic landmark in Cape Town and a reminder of the dispossession and injustice committed to its residents as a result of the Group Areas Act implemented during the apartheid era. In 1966, it was declared as an area for people belonging to the white racial group, resulting in most of the residents of District Six being forcibly removed and its buildings flattened (Pistorius, 2002).

The amount and rate of spatial change that occurred in District Six over the last century has been significant. For this reason it has been selected as a case study for time series mapping. According to Schaffers (personal communication, August 2014) most people understand the history of what transpired in District Six but are not fully aware of the extent of spatial change that occurred through time.

This is where the art and science of time series mapping may be applied to facilitate the understanding of the spatial change of District Six.

1.2 Animated and static maps

The use of computer animation has progressed considerably in the last few decades and has already been realized in various disciplines such as the film industry, architecture and the sciences. It has also proven its potential in cartography in allowing spatial information to be displayed dynamically within map sequences. Animated maps (AM) can therefore depict time directly as a cartographic variable. Various add-ons have been added to GIS packages to run processes depicting change over time such as the Time Manager plugin associated with QGIS. This opens up an interesting space for researching the value of spatio-temporal mapping. We can now ask if animation, linked to cartography can present new perspectives on dynamic data. Spatial sciences have changed from the study of static representations to the study of processes (Karl 1992). District Six was, and still continues to be, an area in constant evolution (McEachern 1998) and the processes that influence the change are manifold, making representation of such dynamism difficult.

1.2.1 Restrictions of static maps

According to Tyner (2010) maps have restrictions, even though they possess functional and practical uses. Map readers are not aware of these limitations and some map makers are not attentive to the same issues, which is evident by the design of a number of published maps. A part of the problem stems from map readers making the assumption that a map shows everything much the same way as a photograph. "Maps are graphic representations, which by their very nature are selective and symbolic, that is, generalized." (Tyner, 2010 p. 9).

Tyner (2010) further explains that it is important that this distinction is made as photographs are not selective, except through the selection of resolution in relation to the scale of the visible objects. The decision of what to include on a map depends on certain factors. This is entirely up to the cartographer, client or interested parties, as the decision is made on which features are prioritised or which areas are emphasised over others. Above all maps are used to communicate information to a specific audience.

1.2.2 Restrictions of animated maps

According to Harrower (2003) the use of animated maps presents a greater cartographic challenge. Creating such a map is time consuming and expensive, and the end result should be informative and striking. Cartographers who intend making use of animated maps should understand the limitations of this medium as a tool. Listed below are some limitations and solutions that should be considered for animated maps:

1. Disappearance – Animation by design involves change. This therefore would potentially cause the observer to miss important information.

   Possible solutions: (a) Allowing the map reader to watch the animation a number of times (on the loop). (b) Play the animation frame by frame by continuing after stops. (c) Regulate speed and alter the frame rate of the animation.

2. Attention – the map reader is unsure where to look or focus attention whilst the animation plays.

   Possible solutions: (a) By placing the information in a logic and systematic manner, the map reader will be more likely to notice significant features or events in the animation. (b) The use of sound prompts and/or narration in directing attention. (c) Using dynamic symbols at key points in the animation such as arrows or flashing symbols.

3. Complexity – one of the flaws of animated maps is that it could try to do too much. “Burdening the user with more information than they can process in real-time undermines the map’s design and may confuse or mislead the reader” (Harrower, 2003, p. 64).

   Possible solutions: (a) Allowing users to turn data on and off, hence reducing overload of information. (b) Regulating animation speed at key points. (c) Allowing users to have control over the speed of the animation.

4. Confidence – People in general have had more experience or training in interpreting static maps/graphs than animated graphics, resulting in lower levels of confidence when faced with the task of interpreting an animation.

   Possible solutions: (a) a brief introduction (less than 30 seconds long) can be deployed to increase user confidence in understanding the data, before it is viewed. Most of the viewers would not be seasoned GIS users, and would therefore be more confident in viewing simpler interfaces. If the interface was more intricate they might feel intimidated and abandon the map.

1.3 Visualisation

Nöllenburg (2007) states that visualisation is an integrated approach providing tools and methods for visual exploration from computing, cartography, image analysis, data analysis and GIS. A human-centred view would be that it is to facilitate, the understanding and knowledge construction of geospatial data. A widely accepted view of visualisation (or geovisualisation) has been proposed by DiBiase (1990) which distinguishes between visual thinking and visual communication.

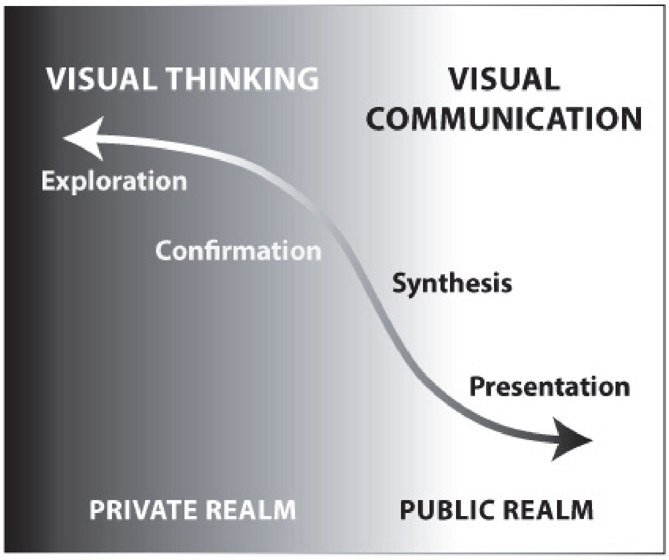

Figure 1. DiBiase's model of visualisation (DiBiase, 1990)

In DiBiase's model (Figure 1), visualisation serves several functions, ranging from activities of visual thinking (exploration and confirmation) to activities involving visual communication (synthesis and presentation). Visual thinking and visual communication are viewed as private and public activities respectively (Tyner, 2010).

Visual thinking involves the processing of mental information through pictures and images instead of words. While we may communicate significantly through words, a large portion of our understanding is connected to our vision.

"In order to successfully facilitate visual thinking it is necessary to understand how the human mind processes visual information" (Nöllenburg, 2007, p. 258).

1.4 Time as a dimension

Peuquet (1994) developed a conceptual framework linking geographic information systems (GIS) to spatial-temporal dynamics, in order to represent time in geovisualisation.

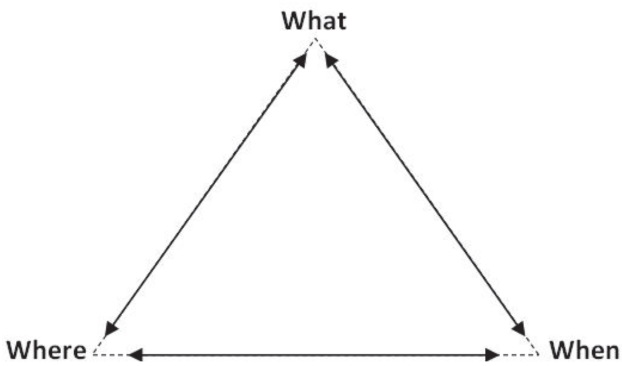

Figure 2. The question triad as reproduced from Peuquet (1994)

As shown in Figure 2, the question triad that describes the geographic experience can be accessed from three angles, facilitating three simple questions:

1. when + where $\longrightarrow$ what: Describe the features or set of features (what) that are present at a specified position or set of positions (where) at a specified time or set of times (when).
2. when + what $\longrightarrow$ where: Describe the features or set of features (where) involved by a specified position or set of positions (what) at a specified time or set of times (when).
3. where + what $\longrightarrow$ when: Describe the times or set of times (when) that a specified feature or set of features (what) involving a specified position or set of positions (where) (Peuquet, 1994).

Ungerleider and Mishkin (1982) as cited in Mennis et al (2000) proves that there is evidence that advocates that people store ‘what’, ‘where’ and ‘when’ knowledge in a particular knowledge hierarchy, associating it with relevant characteristics and purposes.

1.5 Cognitive and perceptive factors

A cognitive system is a constant system whereby a mental representation is constructed of what we are in the process of perceiving (Blok, 2005). Listed below are factors which limit the cognitive and perceptual capacity:

1. Cognitive load theory (CLT) - Cognitive load theory (CLT) involves the cognitive framework of processing information and learning within long term memory. This framework stores knowledge on a permanent basis. CLT offers cartographers, a means of assessing critical and imperative components within the learning process.

2. Change blindness: Hampers the ability of map viewers to note change in animated maps and graphics. It is the difficulty of noticing large amounts of change within visual scenes.

3. Split-attention effect: Another limitation of cognitive load is when an observer needs to provide attention simultaneously to two items that is isolated in time and space (Harrower, 2007).

4. Retroactive inhibition: Can be understood as the information channel from the observers working memory to their long term memory where there is not enough time for the information to be perceived, resulting in what may be considered a “cognitive jam” (Harrower, 2007).

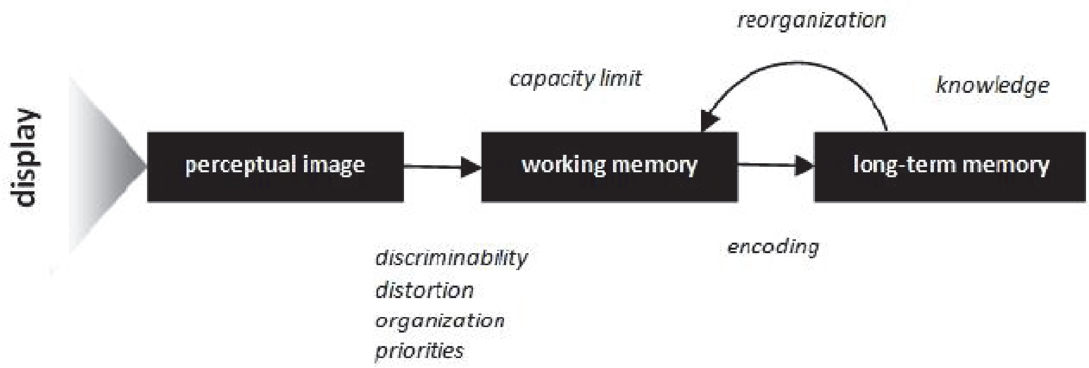

Figure 3. The constant interaction between cognitive structures (MacEachren, 1995)

The constant interactions of the cognitive structures are illustrated in Figure 3 and explained by MacEachren (1995). It begins with the “perceptual image” to the working memory (WM), once factors such as discriminability, distortion, organization and priorities has been made sense of. Contents are then scrutinized and relayed to the long term memory (LTM). The LTM in turns relays the knowledge back to the WM to be accepted or reorganize it accordingly in directing exploration of the visual stimuli.

2. Methodology

The method used for this study involved participants answering a questionnaire after viewing either an animated or static mapping display. Animated and static maps were produced after giving consideration to visualisation and cognitive aspects.

Bertin (1983) classified maps into the following types:

(1) One single static map (SM) – temporal data is displayed graphically depicting variables;

(2) Many maps, in series – a segment of time are displayed by individual continuous maps. One could state that the temporal progression is characterized by the spatial progression which is viewed by the map reader to perceive the change over time. The number of entries is limited as the map reader will find difficulty in following long series of maps.

(3) Animated map (AM) – the temporal data is represented on one display, however no graphical entities are used for the temporal aspect as such.

For the purpose of this study, only type (2) has been implemented in evaluating an AM and SM. The map designs are described in more detail below.

2.1 Static map

From Bertin's (1983) classification point (2) was employed in the method and design used for the static map. This is because the geography changes significantly over time and is the most suited in representing spatial change in series. A series of 13 maps representing District Six over a period of time was printed on one sheet of paper (Figure 4). Prominent features and landmarks have remained over the period of time represented were rendered in a bright colour as reference points. This improved the visualisation and indicated significance throughout the time series.

Considering the amount of information to display, an A2 size sheet was selected to represent all the "time slices" at a scale of 1:15 000, as suggested by Kuhnert (personal communication, August 2014).

According to McLachlan (personal communication, September 2014) to maintain a legible map sequence only one map legend would suffice. By implementing it in this manner the map reader may be attentive to each snapshot. The map legend was therefore placed before the sequencing of the snapshots along with the locality inset indicating the boundary of District Six.

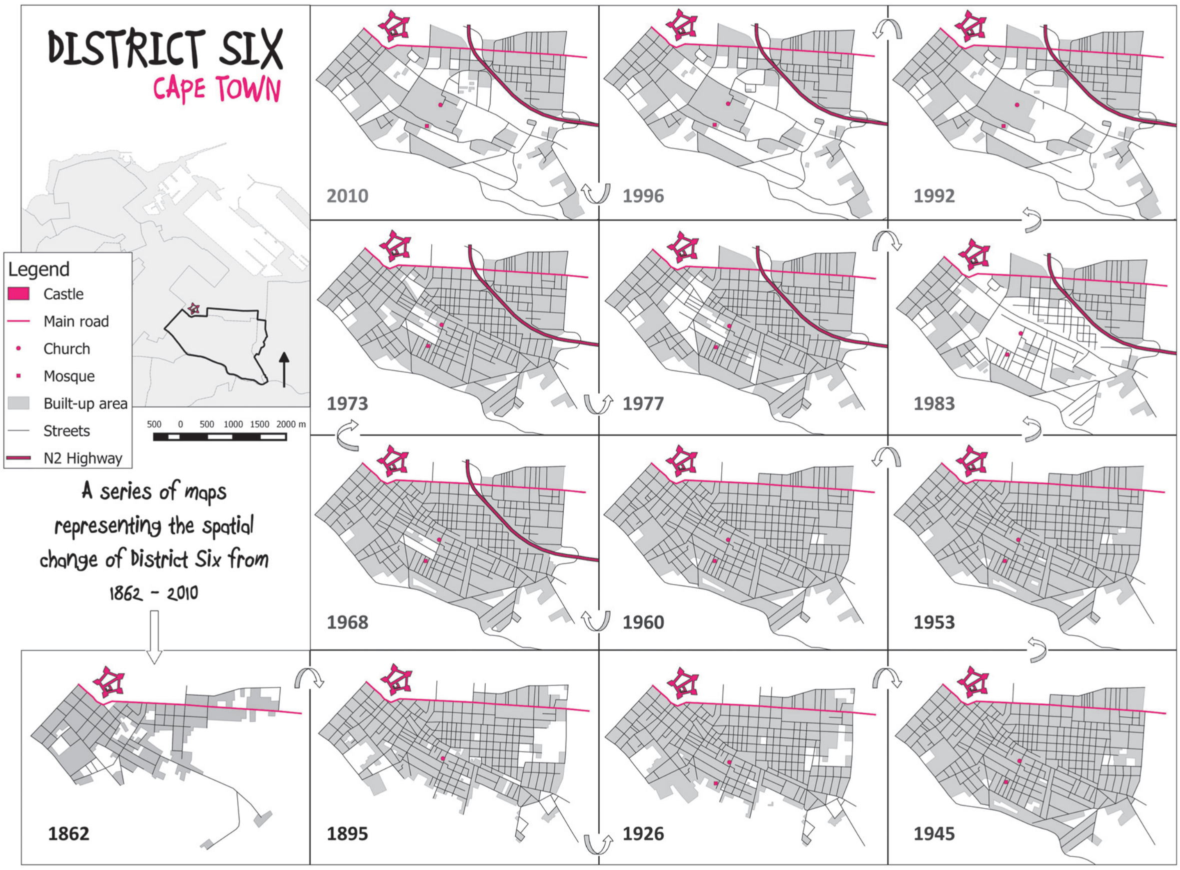

Figure 4. Static time series map of District Six 1862 – 2010

2.2 Animated map

In the animated map, information was presented in a similar way as a time series. This design consideration reduced the cognitive load factor in the hope of improving learning by the map reader (Sweller, 1988). Landmarks were pointed out during the animation to give attention to the viewer. The final animation was entitled "*Animated time series map of District Six 1862 – 2010*" (available at: http://www.youtube.com/watch?v=P-gqonuAO9M&feature=youtu.be). Transitions were placed between snapshots to ease viewing (Moellering, 1980) and played fast enough to show change and reduce change blindness. Consideration was also given to the amount of data presented (Blok, 2005) and duration specifications (Harrower, 2003). The time interval between frames was chosen by conducting preliminary tests by skilled map users, where consideration was given to the amount of information shown per time slice and applied respectively. This ranged from 4 – 4.5 seconds for each time period which included the transitions. The animation was produced using professional video editing software, namely Camtasia Studio 8.

The objective of this research was to evaluate animated and static time series maps with regard to spatial change and information. A group of skilled and unskilled map users were chosen to participate in the evaluation. The question triad described in section 1.4 was related to this study by asking questions that were appropriate to District Six over the time period shown. The questions are shown in Table 1. Figure 5 outlines the procedure that was followed.

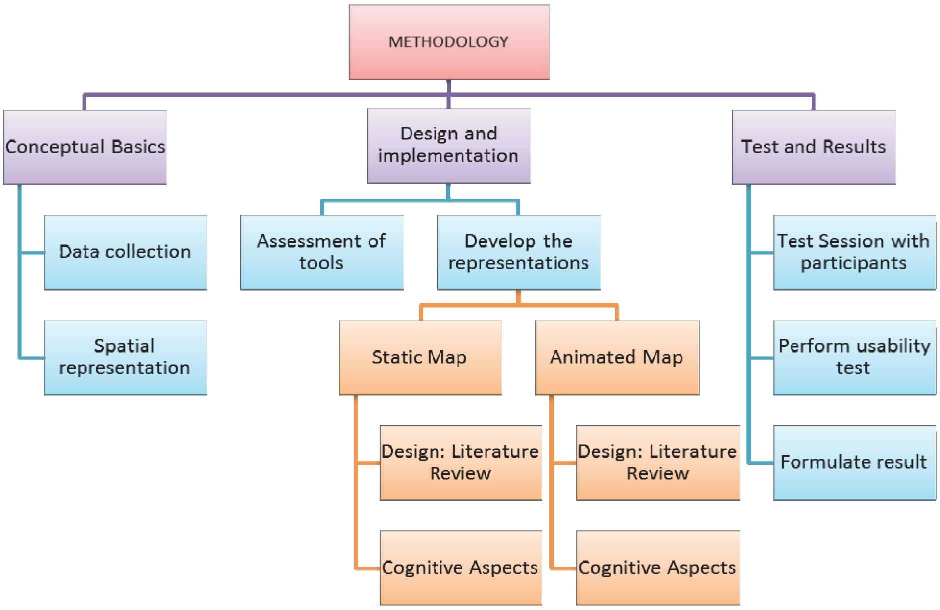

Figure 5. Research methodology framework and map reader design process

3. Results and Discussion

In this section the results of the experiment are presented and discussed. There were a total of forty participants (twenty one males, nineteen females) who viewed either the AM or the SM. Of the forty participants, twenty were employed at the National Geospatial Information (NGI) national mapping organisation of South Africa, and familiar with change detection in mapping. The remaining twenty were guests at the District Six museum in Cape Town and none of them were employed or familiar with work in the geospatial industry. All forty participants were engaged on a one on one basis.

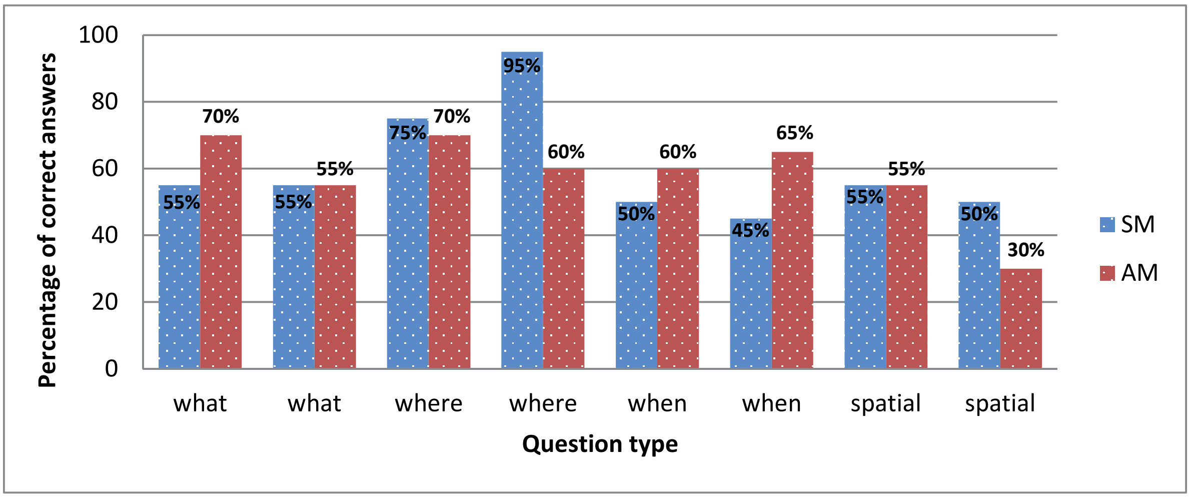

Figure 6. Correct answers of participants in the static and animated map respectively

As highlighted by Table 1, the data in Figure 6 was analysed in respect to the geographic experience (Peuquet 1994). The questionnaire is also displayed as part of the table.

Table 1. The question types and overall correct results of animated and static map in relation to the triad assembly of questions and spatial change

		AM	SM	Overall result
Triad question types	▪ **What** features are always present throughout each period, from 1862 through to 2010?	✓		**Animated map**
	▪ **What** year was there the most drastic changes?	✓	✓	
	▪ **Where** is the castle located?		✓	**Static map**
	▪ **Where** is the Church and Mosque located?		✓	
	▪ **When** does the N2 Highway first appear?	✓		**Animated map**
	▪ **When** does the Church and Mosque first appear?	✓		
Spatial Change	▪ Percentage of **spatial change** of the built up area of District Six between 1926 to 1945		✓	**Static map**
	▪ Percentage of **spatial change** of the built up area of District Six between 1953 to 1983	✓	✓	

Legend:

✓ *These question types was answered better in one of the AM or SM*

✓ *These question types were answered equally by 55% of the participants in each map*

3.1.1 The 'what' geographic experience

70% of participants answered correctly for the AM opposed to the 55% of the SM. However the second 'what' question type shows that both set of participants has equally answered 55% correctly. Therefore preference in this regard has been given to both displays. Overall the AM has an edge in this instance.

3.1.2 The 'where' geographic experience

The static map has surpassed the animated map results albeit by 5% in the first 'where' type question. In the second question 95% of participants answered correctly for the static, significantly more than the animated map's 60%. The participants of the SM display showed greater success, indicating and that the SM is best used for locating spatial features. This result could be attributed to the change blindness aspect and observer attention. The majority of the participants of the animated map indicated this after completing the test and scrutinising the map a second time.

3.1.3 The 'when' geographic experience

The 'when' question type demonstrates that the animated map displays better results in observers noticing when new features appear. The correct answer was selected by 60% and 65% of the AM participants in both 'when'question types respectively. 45% and 50% answered correctly of the SM participants.

This result is not surprising as animated maps are understood to be more efficient in introducing new, large and sudden changes, but it is noteworthy that the participants who answered incorrectly missed these changes. This proves true for factors relating to change blindness.

3.1.4 The 'spatial change' geographic experience

There were two questions which were associated with spatial change between time periods. Observers of both map displays answered equally correct at 55% of the built up area. This indicates that there is no advantage of the SM over the AM and vice versa. It could be attributed to the fact that the remaining 45% of participants had exercised a degree of change blindness, as indicated especially in the first 'spatial' type question. Not much emphasis could be placed on the theory of cognitive load, since the amount of spatial data per time period was generalised and kept minimal where possible. In saying that, the amount of change could have been overwhelming to the map reader, and they might have struggled to be attentive over the full period.

3.1.5 Spatial analysis of District Six

The spatial change of District Six was further analysed as a spatial timeline of the streets and built up areas.

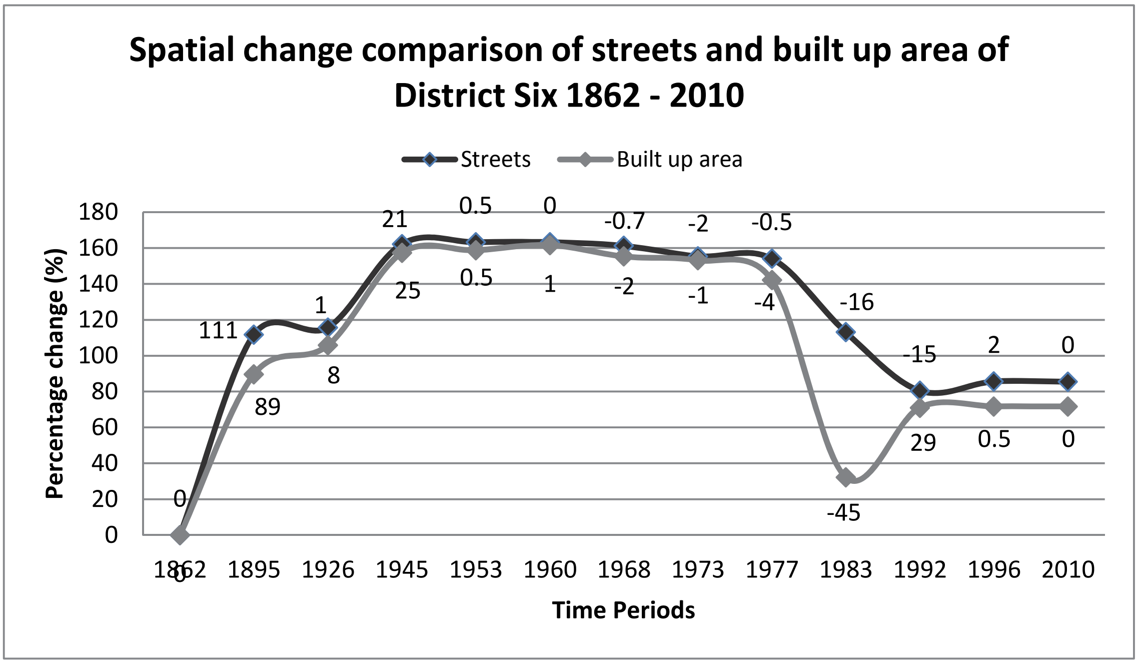

Figure 7. A comparative timeline of the streets and built up areas of District Six 1862 – 2010, including percentage change from each time period

The spatial change of District Six was further analysed by a spatial timeline of the streets and built up areas (Figure 7). It is clear from this visual comparison that both the streets and built up areas have increased and decreased over the time period. There was a steady rise in growth of the urban structures of District Six from 1862 to 1945, followed by a relatively stable period between 1945 and 1977. The demolition of many of the structures resulted in the sharp decline between 1977 and 1983. It then grew from 1983 to 1992, as a result of the addition of the Cape Technikon (Pistorius, 2002). Between 1992 and 2010 not much change in the streets or built up areas of District Six has occurred.

4. Conclusions and Recommendations

It is clear from this study that there are advantages and disadvantages associated with both map displays. However, considering the overall results, neither is overwhelmingly superior to the other. Animated map displays in particular need to have the observer's full attention and the environment is crucial in this regard. This reiterates that observer interest/intention improves transference to working memory.

Interestingly there were two participants who had answered all the questions correctly. Both observed the static map and were not skilled in GIS technology, change detection or familiar with works in the geospatial industry, and neither were from Cape Town. The vast majority of the participants had a 75% success rate in answering the questions correctly. This would give indication that both map representations were efficiently designed as the information and spatial change was clearly shown in limiting all the components of cognitive load. This proves once again that the thought process of the map maker in respect to the audience of the map is critical in communicating the message of the map.

Due to time constraints, other methods in displaying change were not investigated. Another method that could be considered is to create a raster time series display, which could be evaluated as a spatio-temporal and visual cognitive study. For the animated display, it would be interesting to note the cognitive level of the observer if the map was interactive. This would provide the user with control over the display, in contrast to this study, where there was no user control.

The District Six museum has welcomed this initiative of mapping the change of District Six over time as it is part of a unique period in the history of South Africa and particularly Cape Town.

Both the SM and AM are powerful communication mediums at presenting the extent of spatial change that District Six has experienced (Sanger, personal communication, September 2014). Positive feedback was received from the participants as they learned a great deal about District Six from these map displays.

The history of District Six is significant and indicative of Cape Town's apartheid and colonial past. The South African government of the post-apartheid era has since been administering land claims for the victims of forced removals. This history has to be understood in a spatial sense to truly showcase the extent of damage that has occurred. These maps can further be used in schools in facilitating spatial awareness of the impact of the historical events surrounding District Six.

This paper reports on parts of a larger study that also investigated the cognitive difference between various groups of people (e.g. trained vs. untrained map users) but was not reported on here due to space constraints.

5. Acknowledgements

The authors would like to express their gratitude to the management and staff of the District Six Museum for supporting this study.

6. References

Bertin, J. 1983. *Semiology of Graphics: Diagrams, Networks, Maps*. Madison, WI: The University of Wisconsin Press, Ltd.

Blok, C. 2005. Dynamic visualization variables in animation to support monitoring of spatial phenomena. Unpublished PhD thesis, Utrecht University, Utrecht.

Cosgrove, D.E. 1999. *Mappings.* London: Reaktion Books.

Dibiase, D. 1990. Visualization in the earth sciences. *Earth and Mineral Sciences*, 59(2): 13-18.

Harrower, M. 2003. Tips for Designing Effective Animated Maps. *Cartographic Perspectives*, 44: 63-65 and 82-83.

Harrower, M. 2007. The Cognitive Limits of Animated Maps. *Cartographica: The International Journal for Geographic Information and Geovisualistaion,* 42 (4): 349-357.

Karl, D. 1992. Cartographic Animation: Potential and Research Issues. *Cartographic Perspectives,* 13: 3-9.

MacEachren, A.M. 1995. *How maps work: representation, visualization, and design*. New York: The Guilford Press.

McEachern, C. 1998. Mapping the Memories: Politics, Place and Identity in the District Six Museum, Cape Town. *Social Identities*, 4(3): 499-521.

Mennis, J. L., Peuquet, D. J., and Qian, L. 2000. A conceptual framework for incorporating cognitive principles into geographical database representation. *International Journal of Geographical Information Science,* 14(6): 501-520.

Moellering, H. 1980. The real time dimension of three dimensional maps. *The American Cartographer*, 7(1): 67-75.

Nöllenburg, M. 2007. Geographic visualization. In Kerren, A., Ebert, A., Meyer, J. (eds). *Human-Centered Visualization Enviroments.* Berlin: Springer: 257-294.

Peuquet, D. J. 1994. It's about time: a conceptual framework for the representation of temporal dynamics in geographic information systems. *Annals of the Association of American Geographers*, 84 (3): 441-461.

Pistorius, P. (ed). 2002. Texture and Memory: The Urbanisation of District Six. 2nd ed. Cape Town: Cape Technikon.

Sweller, J. 1988. Cognitive load during problem solving: Effects on learning. *Cognitive science* 12(2): 257-312.

Tyner, J.A. 2010. *Principles of Map Design*. New York: The Guilford Press.