CODE RED: MOBILE,
a Live/Synthetic test bed for firefighter training

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Extract from Little Gidding V

TS Eliot, 1942.

*We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.
Through the unknown, unremembered gate
When the last of earth left to discover
Is that which was the beginning;
At the source of the longest river
The voice of the hidden waterfall
And the children in the apple-tree
Not known, because not looked for
But heard, half-heard, in the stillness
Between two waves of the sea.
Quick now, here, now, always-
A condition of complete simplicity
(Costing not less than everything)
And all shall be well and
All manner of thing shall be well
When the tongues of flames are in-folded
Into the crowned knot of fire
And the fire and the rose are one.*

Declaration

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; any editorial work, paid or unpaid, carried out by a third party is acknowledged. This work received ethics approval from RMIT University and ethics procedures and guidelines have been followed.

Patrick B. Quinn, April, 2014.

Research publications and presentations

Parts of the work for this thesis have appeared in the following publications:

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Abstract

The State of Victoria, in Australia, is prone to catastrophic bushfires. In the Linton Fire (1998) five firefighters died in a firetruck burn over incident after a wind change. In the Ash Wednesday (1983) and Black Saturday (2009) a wind change affecting a bushfire caused a major disaster with many deaths. It is important that firefighters in Victoria are trained about the effects of a wind change on bushfires.

Training for bushfires and wind changes in Victoria is generally undertaken as a book or table top exercise. Field exercises can feature a wind change but it is very difficult for crews in a firetruck to understand where the virtual fire is at any one time and its relation to a predicted virtual wind change.

Incident Management Team (IMT) training about the same type of fire for in an Incident Control Centre (ICC) is much easier as generally it will be a map based exercise. It is problematic that major fire incident training in Victoria does not integrate the training of firefighters in the field with the training of IMTs.

CODE RED: MOBILE, a Live/Synthetic training exercise for firefighters was the test bed for the investigation. It was proposed that training packages using CODE RED: MOBILE would give a better feeling for the size, speed and danger of a real fire by providing movies or images of a virtual fire at the real location in which the virtual fire is set.

The prototype CODE RED: MOBILE was tested with thirty volunteer firefighters belonging to the Mt Macedon Group of Brigades of Country Firefighter Association (CFA) of Victoria.

Movies of a bushfire at Hanging Rock in Central Victoria, Australia, were made in a 3D computer game editor, *Sandbox2* provided with the *Crisis Wars* game (crytek.com). Dynamic-static (annotated movies) media were compared to static (annotated screenshots from the movies) media for learning and

decision making about a bushfire, in a location based training exercise for firefighters. These were delivered in the *iPad3* mobile device in the *7scenes* game framework (7scenes.com). The firefighters' movements were recorded with GPS in the decision making phase of the exercise, and analysed with spatio-temporal tools.

The firefighters learned how to use the mobile device and carried out the exercise generally in a satisfactory manner. The dynamic-static and static media were found equally useful for learning and decision making in the mobile training exercise.

Spatio-temporal analyses of the use of the prototype provided valuable information for detecting problems in the design of such exercises and detected unusual performances in the exercise by some participants. These unusual performances revealed either aberrant behaviour or difficulties with the exercise.

Fractal analysis of participants' GPS tracks in the decision making phase of field trial showed the tortuosity of their tracks, from very convoluted to straighter. This fractal analysis uncovered five Domains of spatial scale for the firefighters' movements.. For three of the Domains at different spatial scales, participants were walking freely through open areas, in another Domain they were looking for gaps or ways through internal barriers and at the largest scale Domain they were meeting external barriers and turning back in hair pin bends or recrossing their tracks. This revealed searching and navigation behaviours in the field exercise.

Firefighters, in the decision making phase of the exercise, who saw the dynamic-static movies, walked a shorter distance in less time, but with a more tortuous path, than the other group who saw only static media. Live/Synthetic exercises, containing dynamic-static movies although they may not have effects on abstract learning, may be producing effects on physical and emotional response, or motivation.

These findings demonstrate that the research into the theoretical and practical design concepts produced a useful mobile location based exercise that most participants succeeded in completing. The research also provided a means to analyse the performance of participants, with the prospect that this may be useful for improving mobile field training packages.

The research presented in this thesis leads to the proposition that emergency organisations would benefit from Live\Synthetic mobile training featuring various combinations of firefighters in the field, virtual firefighting appliances, and virtual fires, in conjunction with an Incident Management Team at an Incident Control Centre, with an overview or constructive view, of all live and virtual participants and entities.

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List of acronyms

BKDI	Byram-Keetch Drought Index
CFA	Country Fire Authority of Victoria
DEM	Digital Elevation Model
DEPI	Department of Environment and Sustainability (formerly DSE)
DIS	Distributed Interactive Simulation
DIS	Distributed Virtual Simulations
FBAN	Fire Behaviour Analyst
FFDI	Forest Fire Danger Index
fMRI	functional Magnetic Resonance Imaging
ICC	Incident Control Centre
IMT	Incident Management Team
LBS	Location Based Services
LVC	Live, Virtual and Constructive
OODA	Orient, Observe, Decide then Act
PDA	Personal Digital Assistant
POO	Point of Origin
RH	Relative Humidity
SES	State Emergency Services
TPCK	Technology, Pedagogy, Content and Knowledge

Chapter 1

Introduction

1 Chapter overview

This research developed a prototype *Live/Synthetic training game* for firefighters called CODE RED: MOBILE. This was a test bed for some experiments on mobile learning for firefighters, and trialling the use of 3D computer game editors to create movies and static learning materials of bushfires undergoing a dangerous wind change. Spatio-temporal analysis, including fractal analysis, of individual participant's movements during the exercise, discovered information about participant's performance in the exercise. Averaged Fractal D, a measure of the tortuosity of tracks, for all participants, assisted in the discovery of their navigational responses to the geography and nature of the test area. This type of information is useful for assessing participant's performance and examining the design of the exercise itself.

The motivation for this research was the author's experiences as a volunteer firefighter in Victoria, Australia. The disastrous bushfires that devastated large areas in Eastern Australia, 16th February, 1983, from East Trentham to Mt Macedon in Central Victoria destroyed 29,500 hectares, 7 lives were lost and 628 buildings and 157 houses were burned (CFA 2012a). The author was with the Captain manning the hoses of the Newham Brigade tanker near Woodend in the Macedon Ranges when the water pump failed on Ash Wednesday, 1983 near midnight, as the high temperatures vapourised the petrol in the fuel line. Without water we were engulfed by burning embers. The Captain slowly rolled up both hoses and the truck proceeded back to the watering point where a mechanic got the pump going again and we returned to the fire front. The Captain's demonstration of cool headedness is a long

lasting memory, as is the fear of fire and the personal impact from the seven people who died in the Mt Macedon- Trentham area on Ash Wednesday, 1983.

Figure 1: Annual cost and number of bushfire events from 1967 to 1999 (Middelmann, 2007 p.103).

Figure 1 shows a graph demonstrating the enormous financial cost of bushfire events in Australia, from 1967 to 1999.

Fire brigades also suffer losses amongst their personnel. In the extensive fires of Ash Wednesday in Victoria, 47 people died, 14 of which were Country Fire Authority (CFA) firefighters (Murray & White 1995 p. 216). In the Linton fire, in 1998 (Cheney *et al.* 2001) five firefighters died in a firetruck burn over incident after a wind change.

Next the research questions are presented and then a background of the research follows. Sections on original contributions and an outline of the remaining chapters follow.

1.1 Thesis statement and research questions

The CODE RED: MOBILE test bed, features a Live/Synthetic mobile training game for firefighters, enhancing learning and decision making about a virtual bushfire by delivering visualisations and other media at the fire's real world location.

The thesis statement, above, encapsulates the CODE RED: MOBILE test bed, and the exercise it enabled. The test bed was used for several experiments: one of which compared two treatments of the media used; and another where participants' GPS tracks underwent spatio-temporal analysis. The CODE RED: MOBILE test bed was developed to answer the overarching research question:

Q.1 How can a conceptualisation of a bushfire, as visualisations in a game framework on a mobile device, best assist with the understanding of a virtual bushfire and enable decision-making about its behaviour in the real world location?

This lead, after a literature review, to further research questions:

Q.2 Are dynamic-static visualisations superior to static visualisations for learning about a bushfire, in a mobile, Live/Synthetic, training exercise?

Q.3 How can we record, visualise and analyse participants' movements, in a mobile, Live/Synthetic, training exercise?

Q.4 Can fractal analysis of participants' GPS tracks assist the geospatial analysis, of Phase 2 of the exercise?

The research questions and the thesis statement assisted in developing CODE RED: MOBILE, guiding the scope of the literature review and the development of the test bed and the design of the experiments.

1.2 The background for this research

Training for firefighters and Incident Control personnel is the key to making fire fighting safer. It is paramount to know when to attack a fire and when to retreat. No firefighters died as a direct result of the firefighting on Black Saturday 2009, although two died from related causes. The *Victorian Bushfires Royal Commission* (Teague *et al.* 2010) noted the professional performance of firefighters in the field, but reserved criticism for the Incident

Control Centres whose personnel had shown deficiencies resulting from a lack of training.

The *Victorian Bushfires Royal Commission* (ibid) was told that nineteen fire crews had endured dangerous burn over incidents on Black Saturday 2009, when their fire vehicles were engulfed by flames. A total of 105 fire fighters were involved in the nineteen incidents; all survived (Cowan, 2009). Thus the danger of burn over needs to be emphasised in training, and indeed all CFA Brigades in pre-season exercises rehearse how to ‘make tanker safe’, by closing windows, lowering protection screens inside the cabins and turning on sprinklers that shower the vehicle with water. However, ‘to not have been there in the first place’, is always the first preference. Training emphasises awareness of surroundings and weather changes, as well as of potential escape routes, at all times. This is difficult to train for in the field with any realism.

CODE RED: MOBILE is a test bed for mobile learning and training (Brown *et al.* 2011; Dias 2007; Facer 2004; Sharples 2000, 2007; Sharples, Taylor & Vavoula 2005). It features a Live/Synthetic exercise (Whitted *et al.* 2013; Frank *et al.* 2000; Gourley 2013; Heiniger 2013; Kauchak 2012; Quintana 2013), incorporates a comparison of static and dynamic-static media for learning and decision-making by firefighters (Pfeiffer *et al.* 2009, 2011), and a spatio-temporal (Hägerstrand 1970, Andrienko & Andrienko 2006), Kraak 2003b) and fractal analysis of their movements (Mandelbrot, 1982, Nams, 1996, 2005, Nams & Bourgeoise, 2005, Turchin 1996, Doerr & Doerr 2004).

The firefighter participants were divided into two groups: Group 1 saw static information only, Group 2 saw dynamic-static information, in the form of a movie, as well as other static information, such as maps. Both groups carried a GPS and their tracks were recorded. This measurement and analysis of firefighter’s movements, learning and decision making, in CODE RED: MOBILE, a mobile Live/Synthetic test bed, featuring a simulated bushfire in

a real landscape, assists in validating and improving the design of such exercises.

Jeff Herbert (2008 slide 4) from the *Cubic* defence applications group described LVC training as an enhanced way to train. He defined Live as '*real people in real locations using real equipment*', Virtual Simulation as '*real people in simulators*' and Constructive Simulation as '*simulated entities in a simulated environment*'. Constructive Simulation is a term that is equivalent to wargame, '*the heirs of board games like kreigspiel*' (Macedonia 2002 p. 34.)

The Virtual and Constructive together are also termed the synthetic environment. According to Daly & Thorpe, (2009) quoted in Zalcman *et al.* (2011):

'Synthetic environments are simulations that represent activities at a high level of realism... within a single computer or over a distributed network...They allow visualisation of, and immersion into, the environment being simulated.'

In the Management Training Field (Salas *et al.* 2009 p. 560)

'simulation-based training can be conceptualized as any synthetic practice environment that is created in order to impart these competencies (i.e., attitudes, concepts, knowledge, rules, or skills) that will improve a trainee's performance.'

And these can take one of three forms: role-playing simulations, physically based simulations, and computer-based simulations (Salas *et al.* 2009 citing Summers 2004).

For the CODE RED: MOBILE exercise the bushfire is the problem and information about it is supplied to Group 1 as static visualisations (an annotated still from a movie of the bushfire) and Group 2 as dynamic-static (a movie with a spliced in annotated still image). The movie of the bushfire was made in the *Crysis Wars Sandbox2* (crytek.com) game editor. These are simulations of the bushfire and were created in the *Sandbox2* game editor of

Crysis Wars (crytek.com). The Live element is the participant firefighter in the real world environment of Hanging Rock. The location of the participant as he or she moves about Hanging Rock and marked on the *GoogleMap* in the *7scenes* application on the *iPad3* screen is a virtual simulation of real people. The four houses in the Hanging Rock Reserve exercise area are Constructive Simulations of imaginary buildings and are also located on *GoogleMap* in *7scenes*. In fact the division into these categories of Virtual or Constructive is somewhat arbitrary and Live/Synthetic, where the synthetic term that encompasses all the non human elements, is viewed as appropriate for CODE RED: MOBILE.

Dynamic visualisations of bushfires are a form of geographical visualisation or geovisualisation (Cartwright *et al.* 2004; Andrienko & Andrienko 2006; Kraak, 2003a). Animations have drawbacks for learning (refs) but also benefits (refs). Visualisations (Tufte 1983, Battenfield & Mackaness 1991) are a means of transmitting an expert's mental map (MacEachren 1995) of an area of knowledge or an event to a learner or decision maker. The creation of a visualisation involves a complex process of creating a transmissible version of mental map (MacEachren & Kraak 2001) in the form of a cognitive artefact (Tversky 2000; Campbell 2012; Hutchins 1995; Norman 2007). The transmission requires a conversation between the receiver and the transmitter (Pask 1976, 1992; Hollan *et al.* 2000). 'Reading' of the information contained in the cognitive artefact by the receiver is a complex cognitive process involving perception (Hegarty 1992; 2004), and memory (Buzsáki 2006; Doeller *et al.* 2010; Klatsky 1998; Hartley *et al.* 2006; Jeffery *et al.* 2006). Hence Andrienko and Andrienko (2006, p. 166) defining visualisation as "*making data and the corresponding phenomena perceptible to the mind or imagination of the explorer*".

Decision making requires understanding and planning through analysis and synthesis (Boyd 1995). Training is about learning to do something. Pedagogy is the study of learning. Constructive learning with scaffolding is recognized

as the most practical form of instruction form of pedagogy (Bruner 1973; Kearsley 2012; Andrews & Haythornthwaite 2007).

Live/Synthetic training is sometimes in a serious game-like form (Zyda 2005; Alvarez & Michaud 2008; Sorensen & Meyer 2007). CODE RED: MOBILE is an example of serious game based training. The game like structure provides a framework for learning and decision making tasks. The design of this was informed by ideas from the field of game studies (Gee 2003; Bryce & Rutter 2001; Murray 1997; Ryan 2001; Salen & Zimmerman 2003) and in particular from games for learning (Gray 1995) and mobile games (McGonigal 2003;

Gentès *et al.* 2009; Montola 2005; Benford *et al.* 2006) and location based games (Alvarez & Michaud 2008; McGonigal 2003; Matyas 2007). Ideas from geographic board games assisted (Seville 2011, Bayfield 1997). Simulations and games for learning provided further ideas (Gredler 1996; Fletcher & Tobias 2006).

1.3 Contributions and findings of the research

The aim of the thesis, in summary, is to show that computer game editors are a useful creator of dynamic visualisations of bushfires. These visualisations on a tablet device can be used for training in a location based exercise and analysis of results in the exercise reveal details of participants' behaviours in the exercise and provide data for improving the prototype.

The main contributions and findings from this thesis are that:

- Dynamic-static visualisations are not significantly superior to static visualisations in a location based training exercise for firefighters but both are sufficiently informative for most firefighters to understand and make decisions about bushfire behaviour in the CODE RED: MOBILE test bed application.
- A mobile Live/Synthetic exercise is a viable means of training firefighters about bushfires affected by a wind change.

- Tablet devices can be used in the bush for training.
- Spatial-temporal analysis can reveal ‘*interesting*’ behaviours in a training exercise for firefighters.
- Spatio-temporal and fractal analysis is a useful way to analyse CODE RED: MOBILE participants’ tracks and to determine geospatial aspects of *Phase 2* of the exercise.
- CODE RED: MOBILE suggests a suitable framework for mobile Live/Synthetic training for the CFA and DEPI firefighting organisations in the State of Victoria.

1.4 Chapter Summaries

- Chapter 2 focuses on bushfires, the subject of the prototype CODE RED: MOBILE scenario based training exercise. It provides a history of bushfires in Australia, particularly in the State of Victoria, an introduction to technical details of bushfires, a history of the CFA firefighting organisation. Training for recruit’s Minimum Skills, and firefighters continual Skills Maintenance Drills is outlined. Recent advances in web based bushfire awareness applications are outlined.
- Chapter 3 examines cognitive science and Conversation Theory and from them produces pedagogy that provides underpinnings for the design of the visualisations, maps and other artefacts for CODE RED: MOBILE. Brain science and allocentric and egocentric memory is presented and how they apply to learning and navigation as well as to the development of mental models and the construction of cognitive artefacts. This leads to developing pedagogy suitable for mobile learning. Constructivist modes of learning, in particular using scaffolding or chunking, to construct a cognitive artefact embedding the structure of the knowledge are found suitable for mobile Live/Synthetic learning.

- Chapter 4 looks at Location Based Services (LBS) and reviews research undertaken on mobile games and applications used for learning and mobile location based learning.
- Chapter 5 is about making CODE RED: MOBILE. It describes making the media for CODE RED: MOBILE. Visualisation theory is presented and examined in the context of creating media as cognitive artefacts for delivering learning and enabling decision making. The controversy of whether animated movies are superior to static images, and adjustments such as including static annotated screenshots within the movies do or do not improve learning is discussed. The role that emotion as well as knowledge and experience contributes to learning and decision making is also discussed. This is followed by a section that presents how the movies and screenshots were made using the *Sandbox2* game editor.
- Chapter 6 introduces game theory, including the role of rules. This is followed by a historical account of the development of games with location as a main focus. Mobile, pervasive and location based games are introduced and discussed. Learning with simulations and computer games is considered, as well as location based games. A section describes recent developments in Live Synthetic training. This was mostly undertaken by US and allies military forces. Pararescue is in development in 2014 and is a significant move into Live/Synthetic training for emergency services.
- Chapter 7 gives an account of how conceptualizations of bushfires and disastrous wind changes as visualisations or synthetic elements in a game like framework for learning can be schematized as a *Mobile Learning System*. The bushfire scenario for the CODE RED: MOBILE exercise can be drawn as a schema of three ideas linked by cause and effects. These two concepts were used as the basis for the design of a scenario for the CODE RED: MOBILE exercise and the *Mobile*

Learning System based framework for the *7scenes* mobile application (7scenes.com). This is followed by an account of the two Phases of CODE RED” MOBILE, *Phase 1* the *Information phase*, where the media about the bushfire is viewed at the real world location and *Phase 2* where the *Decision Making* phase is completed. The GPS tracks are recorded for *Phase 2* only. A short section follows on cleaning up the GPS data.

- Chapter 8 presents and discusses the findings of the analysis of the two treatments of the visualisations. It also presents the findings from the spatio-temporal and fractal analysis of participants’ GPS tracks in *Phase 2* of the *Decision Making* phase.
- Chapter 9 contains concluding remarks on the research. It discusses the development of theory for the *Mobile Learning System* and the schema for the virtual bushfire created in *Sandbox2* game editor and delivered in the CODE RED: MOBILE test bed. This, and the experiments conducted in the CODE RED: MOBILE Live/Synthetic training exercise, is assessed in light of the thesis statement and research questions. Avenues for future research and the possibility of the adoption of this type of training system with emergency services are discussed.

1.4 Chapter summary

This chapter introduced the motivations for this research and put forward the thesis statement and the five key questions arising from the literature review that the development and field trial of the mobile location based CODE RED: MOBILE exercise, sought to answer.

In Chapter 2 a history of bushfires in Australia and Victoria is presented together with some technical details used in describing and predicting dangerous fires. Minimum Skills training for recruit firefighters and Skills Maintenance Drills for experienced firefighters are introduced.

Chapter 2

Bushfires in Australia

2 Chapter overview

This chapter provides a history of bushfires in Australia and an account of some aspects of firefighter training for the Country Fire Authority, Rural Fire Brigades in the State of Victoria. There is a description of bushfire features that are vital for firefighters to understand and are also important for residents in bushfire prone areas. There is a presentation of key material that probationer CFA firefighters use to learn about fire behaviour and basic fire fighting.

2.1 A history of bushfires in Australia

2.1.1 The Early Days

In 1797, John Hunter the second Governor of the Colony of New South Wales sent a report to the British government in London (Historical Records of Australia 1914 pp.19-20):

‘We have this last summer experience’d the weather so excessively sultry and dry from the very parch’d state of the earth every strong wind has occasioned conflagrations of astonishing extent... such was the dry’d land and very combustible (sic) state of every kind of vegetation (sic), whether grass or tree.’

Later in the summer of 1797 Governor Hunter (Figure 2.1) issued the first colonial Australian fire warning (Historical Records of New South Wales 1892-1901 p.309):

‘He recommends to their particular attention in the present season to be cautious by enclosing their (hay) stacks with a paling or wattle hedge, or

by any means which may stop the progress of the fire, to hoe up and clean rake and dig a small ditch at some distance round their grain and dwelling.'

Figure 2.1: John Hunter (1737-1821), by William Mineard Bennett, c.1812

(Source: National Library of Australia, <http://nla.gov.au/nla.pic-an2272205>, viewed 24 June 2013)

The first non-aboriginal settlers arrived temporarily in Victoria in 1803. Murray and White (1995) citing Shilling and Rogers (1972 pp.59-60) quoting from the diary of the Rev. Robert Knopwood, chaplain to the new convict colony at Sorrento on the coast near present Melbourne, reported that he saw 'the fires of the natives'. On the 18th January 1804 with the temperature over 38°C two of the marine's huts were burned down (Murray and White 1995 p. 5). The following day with a hot northwesterly wind: *'the country was all on fire around Arther (sic) Seat'*. Arthurs Seat is on the south-east shore of Port Phillip Bay, Victoria. It can be seen from Melbourne. The new settlers and convicts left for Tasmania a few weeks later.

In the 1830s settlers returned to Victoria. Their fire practices differed markedly from the aboriginal inhabitants who deliberately burnt areas of land on a regular basis. Cheney and Sullivan (2008) related that research in Northern Territory and West Australia showed aboriginal people carefully

planned their burns, sometimes small ones and at other times very large ones, depending on the purpose.

Little care with fire was taken by many of the early European pioneers of the State of Victoria and few lessons were learned from the indigenous people.

2.1.2 Black Thursday, 1851

Bushfires that occurred on the 6 February, 1851 were reported about, on the 11 February, by the Argus Newspaper of Melbourne, Victoria in an article entitled 'THE LATE FIRES.' 1851: *'The excitement which this terrible event has caused is without parallel in our colony, all having friends or relatives in the bush, about whose fate the strongest anxiety is felt'*. Black Thursday on the 6 February, 1851 was the worst calamity that befell the citizens of Victoria until the Great War of 1914-1918. A painting by William Strutt indicates the drama of the day (Figure 2.2). He was in Melbourne, though not present at the fire front (Say 2005).

Figure 2.2: William Strutt, artist. Black Thursday, February 6th 1851. H280049. La Trobe Picture Collection. Courtesy of State Library of Victoria. (Source: <http://www3.slv.vic.gov.au/latrobejournal/issue/latrobe-75/large/latrobe-75-P001a.jpg>, viewed 24 June 2013)

By 1851 areas near the coast and ports like Melbourne were occupied with village, farm and town. Murray and White (1995 p.13) described the 'Interior' of Victoria, as being to the north of the Macedon Ranges and Kilmore and west of Geelong. The 'Interior' was still sparsely settled with Europeans and

had few settlements or roads. At this time the non-aboriginal population of Victoria was 77,000 (Murray and White 1995 p.14).

On Black Thursday privately recorded maximum temperatures were observed as 45° and 48.3° (Murray & White 1995 p.13). There had been a period of drier weather beforehand, with hot temperatures and strong dry winds in the weeks immediately preceding Black Thursday. As the temperatures reached a maximum, half to almost all of Victoria was said to be burning. 12 people died but there were probably more deaths. A million sheep were destroyed (Murray and White 1995 p.14). In the 12 February 1851 edition of the Argus newspaper of Melbourne, a letter to the editor from 'A Macedonian' of the Macedon Ranges, to the south of Hanging Rock, in Central Victoria, reported ('BUSH FIRES—MOUNT MACEDON', 1851):

'About mid-day, the whole of Mount Macedon and the ranges were one sheet of flame, careering at the speed of a race horse, carrying all before it as clean as a chimney newly swept. The destruction in the vicinity of the Bush Inn ¹ is appalling...On the Mountain where a number of splitters and sawyers are employed they have lost all...the wife of Dooling was in flames but prudently saved by a man wrapping her in blankets...it will not do for every a man who has more grass on his run than he has stock to eat it, to put a fire stick in merely because he may wish for something green for a lambing flock.'

This letter is the earliest record of bushfires in the Macedon Ranges, and it is possible that Hanging Rock, the site of the prototype evaluation in this research was also affected, considering the large areas involved. The fire in the Macedon Ranges may also have been deliberately lit. The Black Thursday fires which encompassed much of southern and eastern Victoria was likely a conjunction of many smaller fires that had been burning for several weeks in the highlands (Murray and White 1995 p.18). The high temperatures and

¹ Gisborne, south of Mount Macedon.

strong winds on 12 February pushed the conjoined fires southwards into the southern plains of Victoria with disastrous results.

Firefighting was *ad hoc*. People used buckets and hoses. Pastoral stations formed their own brigades and organised and coordinated back burning and direct attack using green boughs (Murray and White 1995 p.19). Mr. Robert Adams a member of the Newham Brigade remembers in the 1930s, before the Newham Brigade was founded, tying a hessian bag to a stick and using that to put out fires (pers. comm. 2012).

2.1.3 Black Friday, 1939

The Black Friday Fires of January 13, 1939 displayed in the map in Figure 2.3 were extensive and devastating. However, only the area to the southeast and southwest of the Macedon Township was affected in the Macedon Ranges district (Macedon is marked with a red dot in Figure 2.3). Between the 6 and the 13 January the range of temperatures at Wangaratta in the northeast of the State had been from 39°C to 46°C. In Melbourne at 9 am, on the 13th January, the temperature was 36°C and at the middle of the day 45.6°. A northerly wind blew at 20 kph, gusting to 60 kph (Murray & White 1995 p.102).

Figure 2.3: Map of the 1939 bushfires in Victoria. (Source:

http://www.dse.vic.gov.au/__data/assets/pdf_file/0018/100926/1939_season_fire_map_web.pdf,
viewed 24 June 2013)

The Bushfires Royal Commission Report and Transcripts of Evidence (1939) determined that 71 lives were lost, as well as 69 timber mills, 700 dwellings and 1.6 million hectares of State forests. About one tenth of the State had burnt (Murray & White 1995 p.102). Since 1851; there had been no fires to equal the same level of devastation in 1939.

Ralph Brown submitted to the Bushfires Royal Commission (Murray & White 1995 p.99) that: *“There was not much (fire) fighting done until the fire menaced the settlers. It was practically impossible to get people to go out and fight a fire unless it was going to injure them or one of their friends”*.

The Fire Brigades Act of Victoria, 1890 had set up the Metropolitan Fire Brigades Boards of Melbourne as well as a rural based Country Fire Brigades Board that was mainly a volunteer service. The Forests Act in 1927

prohibited fires in the open from October to May. This resulted in the Forests Commission rarely being able to light any burn-offs and most private landholders did not burn-off either. Consequently a massive buildup of fuel on the ground occurred in many forested areas and that greatly exacerbated the severity of the 1939 fires (Murray & White 1995 p.101).

The Bushfire Brigades Association had in 1939, a membership of 399 bush brigades. They were self funded in the main with some assistance from insurance companies and shire councils (Murray & White 1995 p.107).

Commissioner, Judge Leonard B. Stretton in the Bushfires Royal Commission Report, 1939 recommended the organisation of State wide and local fire authorities. Their responsibilities were to be the prevention and suppression of fires as well as the proclamation of fire restrictions in times of high fire danger. Subsequently little was done to improve the organisation of the fire brigades or the management of fires. On the 14, 15 and 16 January, 1944 (Figure 2.4) widespread fires occurred again with the loss of 49 people, 500 houses 160,000 hectares of forests as well as 1,000,000 hectares of grassland (Murray & White 1995 p.116).

The article from The Advertiser of Adelaide, South Australia in Figure 2.4 described the fires around Woodend and Gisborne. The wind change, though easing the fires in many areas, accentuated the threat to Woodend, Macedon and the Black Forest to the south. The fire had a 20 mile (32 km) wide front. Mrs. Sarah Lugg 72, a widow, died on a road in Woodend when two walls of flame converged. 37 houses were destroyed in the area. This disaster, in combination with the lack of reform after the 1939 fires, resulted in Acts of Parliament being passed in November and December 1944 to establish the Country Fire Authority of Victoria. Victoria was divided into Regions with salaried Regional Officers (Murray & White 1995 p. 122).

The Advertiser

WITH WHICH IS INCORPORATED "THE REGISTER"

ADELAIDE, SOUTH AUSTRALIA, SATURDAY, JANUARY 15, 1944 * Published Daily—Price 2d.

FIRES TAKE HEAVY TOLL

11 Feared Dead In Victoria

MANY HOUSES DESTROYED

MELBOURNE, January 14.

At least 11 lives are feared to have been lost, and more than 357 houses are known to have been destroyed in the most disastrous series of bushfires experienced in Victoria since January, 1939.

Eight of the victims believed burned to death had not been identified at a late hour tonight.

Those known to be dead are:—

Mrs. Sarah Lugg, 77, who was trapped in the flames while endeavoring to make her way along the road to Woodend.
Mr. Frank White, 40, contractor, of Birregulla.
Mr. Keith Kneeshaw, farmer, of Werribee.

The two men died from burns shortly after they were admitted to the Colac District Hospital.

Four persons were admitted to the Colac Hospital suffering from severe burns.

In the country the townships of Beechworth, Lismore, Hamilton, Dunkeld, Gisborne, Woodend, Carrington, Warncoort, Birregulla, Creswick, Winchelsea, Warrandyte and Daylesford all had an anxious time.

Reports indicated that 63 homes were lost at Beaumaris, 50 at Mentone, 35 in the Hamilton district, 35 in Dunkeld, 20 at Gisborne, 16 at Carrington, 11 at Woodend, seven at Willaura, five at Macedon, four at Penshurst, 50 at Rokewood, 40 at Skipton, 30 at Winchelsea, and 20 at Daylesford.

The fires were located on widely-separated fronts in a huge area confined mostly to the Western District, and they reached as far north as Beechworth. A change of wind in the early evening eased the position temporarily in some areas, but accentuated the position in others, notably at Gisborne and Woodend, where the Black Forest was in danger.

Many Injured

A bushfire blazing on a 20-mile front is threatening Woodend, Gisborne and Macedon. One death has occurred, many people have been injured, and 37 homes have been destroyed. Mrs. Sarah Lugg, 72, widow, of Woodend, was burned to death on the roadway as she tried to escape from walls of flame coming from two directions.

Eleven people had a narrow escape from death when fire encircled the cars and trucks in which they were travelling. Recognising that they had little chance of outdistancing the fire, the men placed the women in a water channel, covered them with gum leaves, and poured water from a 40-gallon tank over their clothing to prevent it from catching fire. Flames leaped over the heads of the party into an adjoining paddock.

Mother and her children in the Beechworth district of Victoria at the ruins of their home, following the recent extensive bushfires.

One life was lost, about 20 homes were destroyed, and more than 500 sheep burnt in devastating fires which swept the Colac district today.

The victim was Mr. Percy White. He was rescued from the flames and taken to the Colac Hospital where he died a few minutes after he was admitted. Mr. White was fighting the fire when the flames enveloped him, and he was dreadfully burned before rescuers found him.

The worst fire in the history of Hamilton swept into the outskirts of the town from the north and west today. Forty homes and all the property and personal belongings in them were destroyed. There were many narrow escapes from death, several persons saving their lives only by leaping into dams as the flames swept towards them. Tonight voluntary squads were caring for the homeless and the smoke-blinded. Others were endeavoring to trace missing members of families.

Roofs Crash

A fierce, hot wind drove the flames before it with incredible speed. Iron sheets ripped from the roofs of buildings crashed into the main street. Almost the entire business centre closed down and thousands fought the flames.

The Hamilton bark mills were destroyed by fire, and the co-sheds in the railway yard later became ignited. The turntable of the Hamilton railway station had its lines warped and twisted to such an extent that it was impossible to move engines in or out of the sheds. A coal loader, valued at £10,000, was entirely destroyed.

Dunkeld was ravaged this afternoon by a fierce fire which swept into the town with amazing rapidity before a strong north wind. Residents had no chance to save their property, and many had to flee for their lives. Thirty-five homes and business premises were destroyed. The mountains are ablaze.

Devastation on all sides is reported from Lismore by returning fire-fighters, who state that houses, cattle, a flax mill and stacks were destroyed by one of the worst fires experienced in the district. Lismore has sent an SOS to Camperdown for food for 200 people evacuated from the nearby towns of Darlington and Derrinallum, which are reported to have been burnt out.

A disastrous fire started in the Winchelsea area today and travelled in the direction of Buckley. The township of Winchelsea is in grave danger.

Bendigo's electricity supply failed at 7.45 p.m. as the result of the most serious fire in the district for many years.

Prisoners Help

Fires which have been causing alarm at Beechworth were still being held in check today, but a fresh outbreak occurred near Lake Zeebar at 4 p.m. and travelled towards the prison settlement. Prisoners, aided by military personnel and local fire-fighters, held the blaze.

Tremendous damage to property was caused by two extensive fires which swept through bayside suburbs in the Cheltenham-Mentone-Beaumaris area today, destroying many houses and leaving more than 100 people homeless.

There were exciting and distressing scenes when the flames reached the residential area near the Beaumaris foreshore in the afternoon and completely destroyed fine homes on Beach road and in adjacent streets.

Figure 2.4: The Advertiser, 15 January, 1944. Creative Commons Attribution-Non-Commercial-ShareAlike 2.1 Australia Licence.

(Source: <http://trove.nla.gov.au/ndp/del/page/2635431>, viewed 24 June 2013)

In 1946 the Country Fire Authority established a training school for Regional Officers. By 1949 there were 33 training schools and training for members in

bushfire suppression and equipment operation commenced on a broad scale (Murray and White 1995 p.129).

2.1.4 Ash Wednesday, 1983

On the 8 January 1983 a fire broke out in the Greendale –Bacchus Marsh district of the Wombat State Forest. It burnt out a very large area (coloured green in Figure 6.7). 1 February, 1983 some workers on the northwestern slope of Mt Macedon accidentally started a fire which burned in a west-southwest direction along the north face of Mt Macedon. The fire in Figure 2.5 continued to burn for several days. During that time a spot fire set alight the author's neighbour's paddock. The fire was fought with wet sacks until the Newham Tanker arrived. An airplane halted the fire by spreading chemical retardant in front of it.

Figure 2.5: Views, from the north, of the Mt Macedon Fire of the 1st February, 1983.
(Author's photos).

On the afternoon of the 16 February, 1983 at the origin of the East Trentham-Macedon Fire, marked as ORIGIN1422 in Figure 2.6, two power lines clashed starting a fire at 14.22 hours. It travelled south-southeast halting at the burnt out area of the earlier Greendale fire. However flying embers started spot fires on the far side of the burnt out area. At 2100 hours the wind changed and the fire burnt east- northeast. The wind is estimated to have

gusted to 100 kph. At Newham the author's weatherboard house was pounded by clods of earth from a ploughed fire break

Figure 2.6: The East Trentham-Macedon Fire 16 February, 1983. Greendale Fire in green burnt on 8 January. Mt Macedon Fire in orange colour burnt on 1 February. The East Trentham-Macedon Fire burnt on the 16 February, 1983. Wind and fire direction black arrows. Time of fire fronts marked on isochrones. Creative Commons Attribution Share-Alike 3.0 License. (Source: <http://bushfirehistory.wikispaces.com/Macedon+Ranges>, viewed 24 June 2013)

to the south for a long period of time. The wind suddenly dropped, there was the most hellish view of distant flames on the horizon to the south and southwest and the vast, broiling dark clouds above, under lit by a bright, evil, blood-red glow. A few hours later the author's midnight shift on the Newham firetruck began. An account of that appeared in Chapter 1.

The Ash Wednesday fire occurred at the end of a long drought. There were 200 fires with 8 major outbreaks. 47 people died, 14 of whom were CFA firefighters (Murray & White 1995 p. 216). 46 of those people died shortly after the wind change. Few people thought that the East Trentham-Macedon

fire would burn over the Calder Highway through Macedon and reach the crest of Mt Macedon after the wind change, but it did and at astonishing speed (Murray & White 1995 p. 226).

The weather had had a profound effect on the fire with a top temperature recorded at Melbourne of 43°. The winds were northwesterly earlier in the day at 68.5 kph, later at the wind change the southwesterlies were blowing at 88.9 kph (Murray & White 1995 p. 228).

In an account of a fatal incident during Ash Wednesday, 1983 by Packham and Pierrehumbert (1990 p. 8):

‘Five of these thirteen victims died in the immediate vicinity of their homes...With the benefit of hindsight it is evident that successful survival strategies require an understanding of the importance of the wind change. In fact, of the 47 deaths on Ash Wednesday, 46 died from injuries sustained immediately after the wind change’.

The coronial inquiry as recounted by Murray and White (1995 p.245) found that the seven deaths in the Macedon area: *‘occurred as a result of insufficient warning, which in this age of advanced technology, is difficult to understand.’* At the time firefighters had had little experience of wind changes that were so sustained and with winds at such a velocity (ibid p.245-246).

2.1.5 The Linton Fire

On 2nd December 1998 five firefighters at Linton, near Geelong, Victoria died whilst attacking a bushfire’s flank (Cheney *et al.* 2001). They were members of the Geelong West volunteer fire brigade. A bulldozed control line was being constructed parallel to the eastern flank of a fire that was burning southwards through eucalyptus forest on hilly terrain. A bulldozer was closing the gap between bulldozed lines. It headed south beside an old track and two fire trucks accompanied it for its protection. The two tankers ran low on water and headed south down the old track to get water. At this point the wind changed from a north-north westerly to a westerly wind. The bulldozer

turned and went back to burnt out ground, the two tankers stayed in the unburnt forest in the path of the now crown fire. Location of the trapped tankers is displayed in Figure 2.7 (Cheney *et al.* 2001). The ground fire had entered the tops of the trees, termed crowning and this is where the winds are fastest. The bushfire burned eastwards through the unclosed gap between the bulldozed lines and over the two tankers. The velocity of winds after the wind change were averaging 30-35 kph and gusting to 68 kph. The fire was about 70 m from the tankers and the time of travel to the tankers could have been up to several minutes and as little as 1 minute 45 seconds (Cheney *et al.* 2001).

Figure 2.7: Linton Fire. © 2001 Taylor & Francis. (Source: Cheney *et al.* 2001 p.3)

They had little time to flee the fire and their only chance would have been to be aware when the wind change was going to arrive and then to be “on the black” where the fire had already burnt or to be to the east of the bulldozed lines.

The fuel load was about 15 tonnes per hectare. Temperatures during the day were 28° Celsius, The Relative Humidity (RH) was 24% and the north-north-west wind was travelling at 44 kph (Cheney *et al.* 2001 p.3-4).

The grasses were partially cured in nearby pastureland. Eucalyptus forest areas had a Drought Factor of 6 and Forest Fire Danger Index (FFDI) of 22 (Cheney *et al.* 2001 p.3-4).

The Drought Factor is calculated from recent rainfall and the Byram-Keetch Drought Index (BKDI). The BKDI is the number of mm of rain required to saturate the soil and can be up to 200mm. The amount of moisture in the soil also depends on the solar radiation at the site which varies according to a site's aspect and slope as well as the time of day and season. FFDI is calculated from the Drought Factor, temperature, RH and wind speed (Lucas *et al.* 2007). The Drought Factor is a measure of the dryness of the fuel. The Grass Fire Danger Index is determined using the same factors except that fuel state is determined by the amount of curing of the grass: 100% cured grass is perfectly dry and 0% is green grass with no visible drying out. The curing is determined visually in the field. The CFA has a team of observers across the State of Victoria, who measure the amount of grass curing.

The Linton Fire tragedy of 1998 occurred on a day with a FFDI of 22 which is a Low-Moderate Fire Rating (Cheney *et al.* 2001). Cheney (2001 p. 1) citing Chandler *et al.* (1983) wrote that parallel attack, where firefighters burn out the flammable materials between the flank of a fire and a road or bulldozed bare earth line is very dangerous if a wind change turns the flank into the head of the fire. Cheney (*ibid*) wrote that ‘*insufficient emphasis has been placed on this problem*’. If the firefighters had been aware of the approaching wind change they would have been able to retreat to safety.

The Linton Incident shows the importance of knowing the consequences of a wind change to firefighters and why the weather is as important to firefighters as is the fire itself. The weather determines where the fire is, and where it will go.

This account provides some of the ideas and terms that are used in fire forensics and fire prediction. Linton was a tragic event but the danger of the wind change has also had appalling consequences for people in Australia on much larger scales. Firefighters, at all levels of experience and skills, need to have a clear idea of what to look for during a bushfire if an imminent wind change is pending. They also have to bear in mind the people who live or work near the firefront. In the Bendigo fires on Black Saturday, 2009, whilst parts of the suburbs were burning, in other areas people were shopping or watching TV, and life continued as normal. The City and its population had little idea of what was happening unless they were close to the fire. Fire fighters and their agencies need to be aware that what occurs in the bush on a small scale can occur in urban areas on a disastrous scale.

2.1.6 Black Saturday 2009

Ash Wednesday 1983 was dreadful but Black Saturday 2009 was the worst fire in the history of Victoria. For this fire a more detailed review is provided as this fire was studied in much more detail than Ash Wednesday or any other previous fire in Victoria.

On the morning of 7 February, 2009, firefighters of the Kilmore CFA fire station received a pager message that there was a fire between the Saunders Rd and the Sunday Creek Rd near Kilmore. David Williams the First Lieutenant in the Kilmore CFA's command vehicle radioed Tanker 1 and 2 and said (McGourty 2009 p.16) "*For Christ's sake stop it crossing Saunders Rd*". Before the tanker crews could outflank the fire it had entered pine and blue gum plantations and was out of control and racing across the countryside in a southeast direction. The Black Saturday fires in Victoria on 7 February, 2009 affected 78 communities and devastated several towns (Figure 2.8).

Figure 2.8: The extent of the Black Saturday fires 7 February, 2009. (Source: http://www.dse.vic.gov.au/_data/assets/pdf_file/0014/100652/StatewideFiresOverview_20090406.pdf, viewed 24 June 2013)

Impact Category	Cost (\$'000,000)	Percentage of Total
Losses		
Residential Buildings and Contents	\$623	21%
Commercial, Industrial and Public Buildings and Contents	\$38	1%
Park Buildings, Contents and Infrastructure	\$34	1%
Public Infrastructure (inc. utilities and roads)	\$7	0%
Agriculture (inc. stock, feed, crops, buildings and fencing)	\$733	25%
Timber (plantation)	\$80	3%
Emergency Response Operations	\$344	12%
Fatalities	\$643	22%
Injuries	\$71	2%
Environment	\$366	12%
Total	\$2,939	
Benefits		
Government Aid and Programs	\$517	26%
Donations	\$389	19%
Insurance	\$1,092	55%
Total	\$1,998	
Net Loss	\$942	

Table 2.1: Costs and benefits of the 2009 Black Saturday Fires. Source: Stephenson *et al.* (2012)

173 people died, 2000 properties were destroyed and 61 businesses. 430,000 hectares were burnt out, as well as 3,550 agricultural enterprises. Numerous schools, police stations, churches, community halls and sports facilities were burnt (DSE, 2013). The monetary costs were enormous, nearly three billion dollars (Table 2.1).

Figure 2.9: The Kilmore East Fire with wind direction times marked. (Source: http://www.royalcommission.vic.gov.au/finaldocuments/volume-1/pf/vbrc_vol1_chapter05_pf.pdf, p.71).

Daily maximum temperatures for the previous nine days had ranged from 35° to 43° (McGourty 2009 p.17). The state was extremely dry. On February 7, 2009 the maximum temperature in Melbourne was 47° (Tolhurst 2009). The map of the Kilmore East fire in Figure 2.9 illustrates the directions that the fire was moving at various times. The fire was initially pushed southeast from Kilmore East by a northwest wind until the fire reached Yarra Glen-Healesville Rd at 1600 hours and Yarra Glen at 1700 hours. At about 1700 hours the southwest wind arrived and began to drive the entire north flank of the fire to the northeast. This wind change affected the Murrindindi fire (pink

tint in Figure 2.9) a short while later and it too burnt to the northeast. Before the main wind change arrived at the Kilmore East Fire, a pre-frontal trough passed over the area (Tolhurst 2009 p.5).

Figure 2.10: Bureau of Meteorology Mean Sea Level Pressure Analysis for 7 February, 2009.

L is a low pressure area, otherwise termed a cyclone or cyclonic system. TC Freddy is a Tropical cyclonic system. H marks a high pressure area or anticyclonic system.

This was unstable air that can lead to the development of thunderstorms. These thunderstorm-like clouds are termed pyrocumulus (Figure 2.11); the development is partly driven by the heat of the fire.

Figure 2.11: A fire in the Macedon Ranges with a pyrocumulus developing. Photograph by the author.

In Figure 2.10 the passage of the pre-frontal trough – the dashed red line, was the cause of the development of numerous pyrocumulus in the Kilmore East and other fires of Black Saturday (Tolhurst 2009 p.5).

To the west of the pre-frontal trough in Figure 2.10 can be seen the cold front. The cold front marks the line between high temperatures ahead of it and cooler areas behind. The area to the east has rising air pressures and behind to the west lower air pressures. The winds to the east of the front are from the north but behind the front the winds are from the southwest. The front itself typically moves from west to east over Victoria and on the ground the wind will turn from a hot northerly in summer to a much cooler southwesterly as the front passes through.

As the front passes further to the east of the State of Victoria the winds swing round to southerly and as the low pressure area loses its influence the winds swing round to easterlies. There is an anti-clockwise progression of the winds at a location as the low pressure system moves over it.

A further factor in the development of the Black Saturday fires was that the upper winds were westerlies high above the prevailing strong northerlies near the ground. The author observed this occurring at Newham. This had a large effect on the main Kilmore East fire, with its attendant smoke plume, which was dragged to the east by the upper winds. This caused the forward bearing of the fire to be about 10° more to the east than the near ground northwesterly wind direction would indicate (Tolhurst 2009 p.6).

As the trough passed over Newham the author observed cumulonimbus clouds developing in all directions and this obscured the view of the pyrocumulus over the Kilmore East fire to the east. A cumulonimbus to the west of Hanging Rock, Newham delivered a strong downdraft that broke branches off trees. This was mistakenly believed by the author to be the cool change. The cool change arrived an hour or more later.

The westerlies in the upper atmosphere at East Kilmore impacted the high altitude levels of the pyrocumulus and pushed smoke and burning embers to the west of the main fire, which started numerous spot fires to the east of the main fire (Tolhurst 2009 p.6). These spot fires developed and burnt parallel to the main fire. At the wind change these spot fires burnt to the northeast, well ahead of the main fire that had turned into a flank fire and also headed to the north east (ibid).

In Figure 2.12 the sounding balloon that was released on 6 February at Melbourne Airport took meteorological recordings at various altitudes. This is carried out twice a day and the findings released as an aerological diagram combining the two soundings. This shows the variations of humidity, temperature, air pressure and wind speed and direction in relation to altitude. Analysis reveals at what levels clouds will develop, the likelihood of rain or thunderstorms, whether the air is stable or unstable and so forth. The far right of the diagram shows wind direction and strength as they vary with altitude.

Figure 2.12: Balloon soundings at Melbourne Airport February 6, 2009. © 2009 Victorian Bushfires Royal Commission, Australia. (Tolhurst 2009)

The short lines, with tails of various lengths look a little like an arrow. A long triangle hanging from the tail of the arrow represents a wind of 50 knots, a long line 10 knots and a short line 5 knots; added together they graphically give the wind strength. The topmost arrow at an altitude of about 16000 m. has a west-northwest wind direction with a speed of 75 knots; the numerical column just to the right of the arrows shows the more accurate 73 knots. The lowest arrow shows a northerly wind and the number reveals it is at 38 knots. The strictly northerly winds reach only up to 1000 m. which is the altitude of the top of Mt Macedon for example. Above that the wind veers gradually more westwards with altitude.

2.2 Government response to Black Saturday 2009

The tragic events of Black Saturday 2009 were examined by the *2009 Victorian Bushfires Royal Commission* (Teague *et al.* 2010). Technical submissions provided much of the information that informed the research into the fire behaviour and weather on the day. Submissions also looked at the firefighting organisations and their management of the fires. There were 67 recommendations from the Commission. On firefighting response there was praise for firefighters' performance in the main (ibid p. 11): *'The fact that there were no firefighter deaths during firefighting activities on 7 February speaks volumes for the emphasis the CFA² and DSE³ had given to training and safety awareness'*. Criticism was mainly restricted to the management and training of Incident Control Centre personnel some of whom were not able to perform to the standard of efficiency required (ibid p. 9):

'Those Incident Management Teams (IMTs) that were poorly prepared or did not have access to fully qualified staff also often had the greatest difficulty managing information flows, which are crucial to the issuing of public warnings and informing firefighters of changing conditions and potential danger. In the light of the evidence, it is plain to the Commission that effective training is essential.'

The communication of fire behaviour and weather changes and the investigation of safety incidents were also found problematic (ibid p.11):

'Firefighters caught in burnovers often lacked the accurate and timely information they needed to avoid risk. Inadequate briefings, communication and communication equipment, maps and weather information were common concerns.'

² Country Fire Authority of Victoria

³ Department of Sustainability and Environment now DEPI, Department of Environment and Primary Industry.

In the document 'Implementing the Government's Response to the 2009 Victorian Bushfires Royal Commission, May 2011', the Victorian Government in one section, presented details of what they had achieved with respect to '*Enhancing capacity and capability to respond to bushfires*' (Victorian Government 2011 p.7):

- *'fire intelligence gathering, analysis and predictive capabilities including the new Phoenix RapidFire simulation tool, which provides up to six hours warning of the direction, speed and intensity of a fire within minutes, rather than hours, of its detection (recommendation 16);*
- *staffing, training, volunteer support, fire-fighter safety, procedures, technology, equipment and facilities in incident and emergency management and on the fire-ground (recommendations 9-15, 17-19 and 21-26);*
- *arrangements for pre-deploying incident management teams on dangerous fire risk days (recommendation 8) and despatching fire-fighting aircraft (recommendation 20);*
- *community information about the forecast of dangerous fire conditions; and*
- *warning systems, most notably the One Source-One Message tool that enables Incident Controllers to broadcast warnings to multiple sources and the Emergency Alert telephone messaging system (recommendation 1)'.*

The time fire predictions must be ready is less than 30 minutes after a new fire is detected, from the author's experience as a fire mapper in the Gisborne ICC.

This history of bushfires in Victoria has ranged from descriptive accounts of early bushfires to recent fires which have been the subject of extensive

scientific and forensic analytical studies, often at the behest of judicial and government authorities. Although not perfect, the firefighting organisations are now more professional, better connected and highly technical emergency responders.

Training practices achieved their current form in the State of Victoria since the Linton Fire of 1998 (Chapter 1 pp. 1-3). This incident, where a burn-over killed 5 firefighters, resulted in a major change in CFA culture from ‘can do’ to ‘safety first’ (Jones 2011). This was demonstrated by the new directive that all firefighters must complete the ‘Minimum Skills’ training before turning out at fires and other emergencies (ibid 2011).

2.2.1 Fire Warnings Advice

With advances in weather prediction it is often possible to get weather forecasts that are reasonably accurate for nearly a week ahead. Predictions of cyclones and disastrous bushfire days have become more trustworthy. Bushfire warnings can be given several days in advance and people in potentially fire affected areas can plan accordingly.

	GRASSLAND FIRE DANGER INDEX	FOREST FIRE DANGER INDEX
CODE RED	150+	100+
EXTREME	100-149	75-99
SEVERE	50-99	50-74
VERY HIGH	25-49	25-49
HIGH	12-24	12-24
LOW-MODERATE	0-11	0-11

Table 2.2: Fire Danger Ratings are derived from Grassland and Forest Fire Danger Indices

The Victorian Fire Agency Bushfire Handbook 2012-2013 Edition 2-September (Victoria 2012 p. 51) shows that a CODE RED fire danger rating is declared when the Forest Fire Danger Index (FFDI) exceeds 100 or the Grassland Fire Danger Index exceeds 150. Table 2.2 is a summary of the fire danger ratings and associated danger indices. These ratings were introduced in the summer of 2009/10 as a result of findings from the Black Saturday tragedy.

The community is expected to understand and use these Fire Danger Ratings to determine their action during a fire emergency. Indications in Table 2.2 such as ‘Homes are not designed or constructed to withstand fires in these conditions’ for a CODE RED fire danger day, provide little comfort to the home or business owner, or to the firefighter. Thus on CODE RED days in high risk bushfire and grassfire areas retreat is probably the only option. However on lesser Fire Danger Rating days, especially where the property is not in a forested area, various strategies can be implemented by householders and firefighter agencies to improve the saving of life, property and environmental value.

FIRE DANGER RATING	WHAT DOES IT MEAN?	WHAT SHOULD I DO?
CODE RED	<p>These are the worst conditions for a bush or grass fire.</p> <p>Homes are not designed or constructed to withstand fires in these conditions.</p> <p>The safest place to be is away from high risk bushfire areas.</p>	<p>Leaving high risk bushfire areas the night before or early in the day is your safest option – do not wait and see. Avoid forested areas, thick bush and long, dry grass. Know your trigger. Make a decision about: –when you will leave – where you will go –how you will get there –when you will return –what you will do if you cannot leave.</p>

Table 2.3: The CODE RED rating and CFA advice on what residents should do in the event of a fire.

Table 2.3 is derived from the CFA website's Mount Macedon Community Information Guide- Bushfire (CFA 2012b), which is available on-line for residents.

Householders, farmers and businesses can take measures that will lessen the impact of a forest or grass fire. These measures are not only preparatory work such as clearing fuel from around buildings but also taking part in training about bushfire behaviour. Most experienced firefighters and many long term residents of fire prone rural areas have a good understanding of how local fires will behave. Many new residents however do not have a feel for the land or knowledge of how fire and weather can impact disastrously on their new neighbourhood.

Maps, illustrated stories in newspapers, and 3D animated views of fires burning over a landscape, can show firefighters or residents the dangers of the wind change in their neighbourhood.

2.2.2 'Minimum Skills' for a firefighter

New recruit firefighters, with a trainer provided by their brigade, gain 'Minimum Skills' through a course undertaken using the Wildfire Firefighter text (CFA 2006) and by undertaking practical training sessions.

CODE RED: MOBILE was designed for firefighters who are assessed competent in the 'Minimum Skills'. However, in order to design CODE RED: MOBILE a higher level of training was necessary. The author completed the *Fire Behaviour Analyst* course with instruction and ongoing mentoring provided by the DSE. Annual briefings are hosted by the DSE just before the fire season. In addition the author completed several mapping courses delivered by the DSE and CFA. The maps generally are for fire predictions. The matter in this chapter is for two purposes; firstly it provides an outline of the information that is needed to understand fire behaviour in Victoria. This research was to ensure, as far as is possible, that the scenario created for CODE RED: MOBILE was a realistic simulation of a bushfire. In addition the

material in this chapter provided a background for the much simpler information that the firefighter participants were expected to know for their 'Minimum Skills'; a selection of which were the subject of the CODE RED: MOBILE exercise. (In addition as of 2012-2013 'Skills Maintenance Drills' have been introduced to document training exercises that CFA brigades should carry out. This is examined later in the chapter.)

The 'Minimum Skills' in relation to fire behaviour and weather can be found under the evidence of competency guide provided online (and these are similar to the CFA assessment processes for 'Minimum Skills') for the PUAFIR204B *Respond to wildfire* course, by the Australian Government (2013 p.7):

'Assessment must confirm the ability to: react to changing wildfire behaviour due to changes in weather, topography and fuel conditions.

Context of assessment: Competency should be assessed in an agency approved simulated and/or field-based workplace environment.

Method of assessment: In a public safety environment assessment is usually conducted via direct observation in a training environment or in the workplace via subject matter supervision and/or mentoring, which is typically recorded in a competency workbook... Assessment may occur in an operational environment or in an industry-approved simulated work or in an agency-approved simulated work environment'.

The PUAFIR204B *Respond to wildfire* course (OTEN 2009 p.1) is used by a wide range of organisations that require personnel with fire fighting skills. The CFA does not use this course for delivering 'Minimum Skills'. However its curriculum, is very similar to the curriculum, that appears to be the basis of the Wildfire Firefighter text (CFA 2006) and associated practical exercises. Here we will use some of the information on assessment items for the units of learning on: '*Observe and react to wildfire and weather conditions*'. These are all relevant to firefighters tackling a bushfire and provide a guide to what

was included in the CODE RED: MOBILE exercise. With the constraints of the mobile exercise only a few items were covered and there was no reporting to a supervisor (op cit p. 1):

‘Unit Title: Respond to wildfire

Observe and react to wildfire and weather conditions:

- *1. Conditions at the fire are observed and their effect on fire behaviour and development are noted and reported to supervisor*
- *2. Weather conditions and changes to fire behaviour are observed and reported to the supervisor*
- *3. Variations in terrain, fuel types and fuel arrangements are observed and effect on fire behaviour is reported to the supervisor as required*
- *4. A safe escape route or refuge is identified and maintained at all times*
- *5. Communication is maintained with other Firefighting personnel and the supervisor throughout operational activities’*

The usability and efficacy of training courses can themselves be investigated with respect to participants and their organisations. His Honour David Jones’s report on firefighter training stated that (2011 pp.149-150): *‘The WPI Report 2008 was an Interactive Qualifying Project submitted to the Faculty of Worcester Polytechnic Institute (WPI) in partial fulfilment of the requirements for the Degree of Bachelor of Science’.*

The Project asked firefighters online and 258 firefighters by telephone for their opinions on CFA training (ibid pp. 149-150:

‘Volunteers seemed generally satisfied with the training they were receiving... An overwhelming number of volunteers felt that they do not receive enough hands on instruction and that to be properly trained, they need more practical instruction.’

This indicates that there is a demand from firefighters for more practical hands-on training. The 'Skills Maintenance Drills' have also addressed some of these issues. CODE RED: MOBILE as a prototype training package may provide a partial solution to this desire adding a mobile element to the exercise regime.

The 'Minimum Skills' here, are regarded as equivalent to the competencies outlined above for the *Observe and react to wildfire and weather conditions* section of the PUA FIR204B *Respond to wildfire* course. In the recruit course this is learned from the Wildfire Firefighter text (CFA 2006). 'Minimum Skills' are still a prerequisite for completion of the probation period of CFA membership and a basic level of fire knowledge.

In the next section of this chapter the information from this text is presented. The CODE RED: MOBILE exercise was premised on participants having a reasonably good grasp of the knowledge delivered in the Wildfire Firefighter text (ibid). Firefighters who were participants in the prototype CODE RED: MOBILE exercise in 2012 had not experienced any of the 'Skills Maintenance Drills' at that time.

2.2.3 Firefighter training about bushfires

The first section of this chapter was devoted to a brief exposition of the history of wildfires in Victoria. The fire fighting services and the community throughout that history have attempted to ameliorate the severity of fire with increasingly complex and sophisticated prevention and response systems. Firefighter training is part of that response and CODE RED: MOBILE is an experiment and pilot application that sought to test a new approach to training that may assist in providing more 'hands on' and 'practical training' as respondents to the WPI Project indicated they required (Jones 2011).

In the Victorian CFA basic firefighter training is carried out by the elected officers of the local CFA Fire Station and is usually led by the Training Officer. A standard text is issued by the CFA to new recruits. It is called

Wildfire Firefighter (CFA 2006) and is a joint publication of the CFA, the DSE and the State Government of Victoria. The book covers: Safety on the Fireground; Fire Science; Wildfire Behaviour; Wildfire Development; Equipment Stowage; Hand Tools; Hose and Fittings; Wildfire Extinguishing Agents; Pump Operation; Radio Communications; Preparing for Response to Wildfire; Proceeding to the Fire and Combating the Wildfire.

CFA recruits are trained by an officer by working through the book in a series of lessons at the fire station. Tests have to be completed. The course can be repeated until the recruit passes. Firefighters are also expected to attend a training Sunday once a month throughout the year where practical and desktop exercises occur. In addition further specialist courses can be undertaken at a variety of venues.

In this section a selection of the basic information that a firefighter would have received in their basic course is presented. This is extracted from the relevant chapters in the CFA's Wildfire Firefighting book (CFA 2006).

Figure 2.13: The shape of a fire varies with the wind speed. (CFA 2006 p. 94)

Figure 2.13 shows the variation in the shape of a fire with different wind speeds. A fire expands outwards from the point of origin (POO) in a circle when there is no wind. With a moderate wind the fire extends southwards. The CFA diagram is a simplification, as the flanks and back fires do continue

burning outwards in many cases. Under a strong wind the shape becomes elliptical or cigar shaped. Note, that under all winds, fires tend to expand laterally at the rate of a no wind fire.

Figure 2.14: The parts of a fire. (CFA 2006 p.105)

The parts of a fire are shown in Figure 2.14. Fingers of fire follow vegetation patches and run up ridges in the landscape. Spot fires, the result of embers flying forward of the head fire can coalesce to form a new head fire. The flanks are either side of the fire. Imagining oneself standing at the back of the fire looking forwards towards the head fire, then to the left is the left flank and to the right is the right flank. This seems obvious but can be difficult for an inexperienced firefighter to work out when not located at the rear of the fire.

Figure 2.15: The effects of a wind change on a running fire. (CFA 2006 p. 95)

A wind change is affecting a fire in Figure 2.1.15. It has burned southwards under the influence of a northerly wind in A. A wind change from the south west is impacting the fire at 1330 hrs in B. In C the fire has changed direction. The left flank fire has become the head fire and with an approximately 4 fold increase in the width of the fire front, is now burning towards the north east. This change in fire direction often occurs in a short period of time and can put firefighters and communities at great risk.

Firefighters when attacking a moderate fire will attempt to put out it out by proceeding either side of the fire up the flanks, starting close to the POO, and by working forwards pinch out the head of the fire. In a more dangerous fire as in Figure 2.16 the fire truck on the left flank of the fire would be

Figure 2.16: The wind change in a serious fire. (CFA 2006 p. 28)

removed well ahead of the wind change. The left flank is technically the left side of the fire as seen from the point of view of someone looking forward from the origin of the fire (which is at the top of the diagram). Thus the fire truck in danger is the one between the before and after the wind change illustrations. Planning for this is required in advance as the left flank ahead of a wind change is a very dangerous place to be if egress has not been considered. In Figure 2.17 the concept of anchor points is seen. They are easily accessible places to which a tanker or firefighter can go and from which there is safe egress.

Figure 2.17: Anchor points are specified places where firefighters and vehicles can easily escape. (CFA 2006 p. 50)

Figure 2.1.18 shows parallel attack on a fire. The road is the anchor point for both flanks. The bulldozers are creating a mineral earth barrier. The

Figure 2.18: Parallel attack of a fire. (CFA 2006 p. 246)

bulldozers are followed closely by the fire trucks. Firefighters, on the ground, burn out vegetation remaining between the fire and the barrier and other firefighters patrol outside the barrier to make sure the fire does not escape. In

some grass fires the tankers will go onto the black and fight the fire from the inside.

This basic introduction equips the recruit firefighters with the core knowledge for safe and successful firefighting. This foundational knowledge or 'Minimum Skills' is expected of all CFA firefighters.

The basic *Wildfire Firefighter* course outlined in Chapter 6 is now backed up since 2012 by an annual sequence of suggested exercises termed the Skills Maintenance Drills. In Fig 2.19 the outline of *BF003 Bushfire Safety and Survival* training session is provided.

<div> <div>Bushfire</div> <div>CFA</div> </div>		<div> <div>CFA</div> <div>Bushfire</div> </div>	
Bushfire Drill <i>*BOSP: Bushfire</i>	BF003: Bushfire Safety and Survival	Resources	<ul style="list-style-type: none"> ▶ Instructor/Safety Advisor. ▶ Brigade Tanker(s). ▶ Minimum crew: four.
Objective	To safely ensure skills readiness for an entrapment scenario in a CFA tanker in a bushfire environment.	Drill Scenario	<i>Bushfire Safety and Survival</i> (Time: 30 min) The crew will be responded via a six figure grid reference to a bushfire at the drill location. Simulated weather is as per a mid summer Total Fire Ban day.
Outcome	At the completion of the drill, crews are anticipated to have achieved the following outcomes. <ul style="list-style-type: none"> ▶ Identified hazards. ▶ Safely and correctly managed all hose and water supplies. ▶ Satisfactorily employed the safety and survival systems and procedures. 	Crew Briefing	<ul style="list-style-type: none"> ▶ On arrival the OIC is briefed to run out one line, two lengths of 38 mm hose and provide a rake hoe and an axe to the branch operator's location and simulate fire fighting activities. ▶ When the above activities are completed to the OIC's satisfaction the order is given to undertake crew entrapment procedure.
Activity Credits	<ul style="list-style-type: none"> ▶ ACT0002 Draught Water ▶ ACT0003 Operate Pump and Deliver Water ▶ ACT0029 Incident Controller ▶ ACT0053 Bushfire Behaviour ▶ ACT0054 Bushfire Suppression ▶ ACT0056 Radio Operations ▶ ACT0075 Work in a Team 	Safety Considerations	<ul style="list-style-type: none"> ▶ Pre-deployment instructions. ▶ Safety zones. ▶ Working with Machinery and Aircraft. ▶ Wearing of correct PPE. ▶ Hydration. ▶ Occupational hazards. ▶ Health and well being.
Pre-drill Considerations	Consider consulting relevant CFA training material where required. A brief theory session covering the Key Points prior to the scenario is highly recommended.	Key Points	<ul style="list-style-type: none"> ▶ LACES – WATCHOUTS – Standard Fire Orders. ▶ Red Flag Warnings. ▶ Anchor points. ▶ Radio communications. ▶ Chief Officer's Pre-summer Briefing (if available). ▶ Reserve water levels on tankers.
Instructor Notes	<ul style="list-style-type: none"> ▶ Select a suitable location at which to conduct this drill. ▶ Ensure this drill is conducted in a safe and appropriate location. ▶ Consider the Area's water restrictions before conducting this drill. ▶ A visual inspection and risk assessment of the selected training site should be carried out prior to the training exercise. ▶ All crews are to wear full PPC. ▶ Ensure all participants receive a Safety Briefing. ▶ Consider running this drill several times to enable crews to swap roles. ▶ This drill is deemed to be completed at the discretion of the Instructor. ▶ The Instructor is to utilise the Training Exercise Evaluation Tool to assist with the Drill Debrief. ▶ Ensure a Training Exercise Debrief is conducted. 		
<div> <div>Edn 1 – February 2012</div> <div>SAFETY FIRST</div> <div>Skills Maintenance Drills</div> </div>		<div> <div>BF003-2</div> <div>SAFETY FIRST</div> <div>Skills Maintenance Drills</div> </div>	

Figure 2.19: Skills Maintenance Drills, CFA, Edn 1, February 2012, BF003 Bushfire Safety and Survival, CFA.

Code	Short Name
BF001	GRASSFIRE
BF002	SCRUB FIRE
BF003	BUSHFIRE SAFETY AND SURVIVAL
BF004	COMMUNICATIONS
BF005	PUMPING OPERATIONS
BF006	SPOT GRASSFIRE
EMR001	EMR BRIGADE SKILLS
	MAINTENANCE
GEN0001	GENERAL SKILLS MAINTENANCE
IN001	MVA - WASHAWAY
IN002	MVA - PERSONS TRAPPED
IN003	MVA - CAR FIRE PERSONS TRAPPED
IN004	MOTOR VEHICLE - GAS LEAK
IN005	MOTOR VEHICLE - FUEL LEAK
IN006	NATURAL GAS LEAK
IN007	INDUSTRIAL INCIDENT
IN008	HAZMAT - IDENTIFICATION
IN009	HAZMAT - EMERGENCY DECONTAMINATION
IN010	HAZMAT - MAJOR INCIDENT
IN011	AIIMS - INCIDENT MANAGEMENT TEAM
NS001	MOTOR VEHICLE FIRE - RURAL SETTING
NS002	MOTOR VEHICLE FIRE - SHOPPING CENTRE
NS003	TRUCK FIRE - TIPPER COMPLETE WITH TRAILER
NS004	HAYSTACK FIRE
NS005	POWER POLE FIRE
NS006	DUMP-MASTER FIRE
NS007	GAS CYLINDER FIRE
ST001	RESIDENTIAL FIRE - DEFENSIVE TACTICS
ST002	RESIDENTIAL FIRE - DT-ISOLATED STRUCTURE

Table 2.4: The Skills Maintenance Drills. (Skills Maintenance Drills, CFA, edn 1, February 2012)

Table 2.4 displays the complete list of drills for a CFA Firefighter. The only one that explicitly mentions a wind change is BF004 Communications, a radio communications exercise that specifies sending a Red Flag warning message of an impending wind change at a fire. A Red Flag warning is a significant change in conditions where safety is compromised. The BF003 Bushfire Safety and Survival drill includes a burn-over of a firetruck activity which sometimes is the result of a wind change. There is therefore, in the author's opinion, a need to include an exercise drill or part of one that explicitly examines the challenges of a bushfire with an impending wind change. This may take the form of a mobile location based exercise drill with visualisations provided as part of the learning material. Mobile exercises which also link to

firefighters training records may be able to automatically record their involvement together with assessments by the trainer.

That mobile training may be the way forward is echoed in a recent publication by the U.S. Army.

Martin Dempsey, General, U.S. Army Training and Doctrine Command (U.S Department of the Army, 2011 Foreword):

‘The Army Learning Concept 2015 does not focus on any particular technology, but rather focuses on the opportunities presented by dynamic virtual environments, by on-line gaming, and by mobile learning. It speaks of access to applications, the blending of physical and virtual collaborative environments, and learning outcomes...The Army Learning Concept recognizes and addresses the arrival of a new generation of Soldiers in our ranks who have grown up in a digital world.’

Firefighters use mobile devices in their daily lives and for firefighting; from GPS in the firetruck, to pagers and a UHF radio on their belts and a mobile phone in the pocket- they have become thoroughly digital.

The review of ‘Minimum Skills’ and ‘Skills Maintenance Drills’ training found no mention of the use of mobile training. However the CFA’s FireReady application (Figure 2.20), downloadable from iTunes for *iPhone*, *iPad* and *iPod* revealed that the CFA organisation, its members and the general public are using mobile devices in preparation and readiness for fires. ‘*Mapscape - Emergency Victoria*’ was trialled in the 2011/12 fire season by emergency service organisations, including CFA, DSE and SES (De Sanctis 2011). This is a mapping application for the *iPad*.

Figure 2.20: CFA FireReady by Collabforge Pty. Ltd. Copyright © 2013 Apple Inc. (Source: <https://itunes.apple.com/au/app/cfa-fireready/id356559665?mt=8>, viewed 6 July 2013)

The implementation of appropriate ‘Skills Maintenance Drills’ onto mobile devices could provide an interesting new direction in training for the CFA following General Dempsey’s suggested focus for training in the US Army.

2.3 Chapter Summary

This chapter presented a history of bushfires in Victoria and the consequent development of fire services. As the population grew, settlements proliferated and urban areas expanded and bushfires became more dangerous. The Country Fire Authority was established as a State funded organisation in 1944 (Murray & White 1995 p.122) after the disastrous 1944 fires. Little had been done subsequent to the 1939 fires to reform the then firefighting organisations. The earlier Bushfire Brigades Association brigades were self funded with contributions from insurance companies and local shire authorities. The Ash Wednesday Fires of 1983 and Black Saturday 2009 were devastating and each was forensically and legally examined by Royal Commissions. Between these two major disasters in 1998 the Linton fire in which 5 firefighters died after a wind change, produced a major change in training when the ‘Minimum Skills’ benchmark was introduced. This was to

ensure that all active firefighters had completed a comprehensive training course, including a practical component before they were sent out to fight a fire. The publication of the Wildfire Firefighter text (CFA 2006) became the basis of the theoretical training.

This chapter also gave a detailed account of Black Saturday 2009 describing how the pre-frontal trough exacerbated the formation of pyrocumulus and the wind change compounded the disaster by turning the already massive fire into one with a huge firefront that went in a new direction. Knowledge of these details about weather systems and the detailed fire behaviour of pyrocumulus were necessary to the development of the scenario itself. CODE RED: MOBILE incorporated a very simplified version of a relatively small fire undergoing a wind change. However to an extent the technical details are similar to a major fire.

His Honour David Jones' report (2011 pp. 149-150) indicated that firefighters opinions were that they needed more hands on practical training. They also wanted more assessment at the brigade level and more online training information.

The introduction of the 'Skills Maintenance Drills' since 2012 with a set of learning materials for training exercises is a major advance in providing professional training for firefighters. The author would maintain however that there is also a need for location based training delivered with mobile devices in line with General Dempsey's comments (2011) for training in the United States Army.

It is very difficult to reproduce the complexities of a wind change affecting a simulated fire using printed and oral information in a field exercise. It was proposed for this research that mobile location based training scenarios may be able to do this.

It is suggested that a mobile device mounted package would provide a platform for learning about the dynamic nature of bushfires. Heterogeneous

information including visualisations of bushfires, static and animated can be used to train for decision making about fires undergoing a wind change. Visualisations can be very useful to spatio-temporal decision making. For example the State Control Centre (SCC) in Melbourne uses an application called *Phoenix Rapidfire* whose output can be displayed as a partially 3D animation in *Google Earth* (see Chapter 6).

Field training for a CFA Brigade is often more about the equipment's operation rather than its use in a simulated event in a real world location where multiple appliances might be deployed. However the Newham Brigade in early 2012 ran an exercise where firefighters on tankers had to imagine where a fictional fire front was on a local farm. The truck at one point drove back and forth over the fire front with the driver not being able to imagine where the fire edge was located. In addition whilst the fire trucks dealt with spot fires, real fires that had been deliberately lit, the predicted fictional wind change had likely destroyed most of the farm assets. It is proposed that a scenario-based training exercise provided on a mobile tablet, can assist with locating fictional elements of an exercise. This exercise can take place within a game-like framework.

The author watching his son, in 1999, playing *The Legend of Zelda: Ocarina of Time*, a game played on a television screen using a hand controller connected to a *Nintendo 64* video game console, considered such a game might be a useful method to learn about physical geography. The game had a 3D terrain and a mobile main character. However there was no means of editing or changing the 3D terrain or other aspects of the game.

Computer games such as *Tribes 2* (Dynamix, USA, originally, later Sierra Entertainment, Inc., USA) with large outdoor terrain, detailed indoor settings and with an included editor appeared in early 2001. *Unreal Tournament 2003* or *UT2003* was released in early 2003 (Epic Games, Inc., USA). The included editor allowed a developer to change the game space to a chosen local terrain and allowed for the overlay of maps and satellite pictures. To add an active

bushfire would require further technical developments in computer games. In recent years the *Crysis* series (Crytek, Germany) provided such a tool. These simulations could be recorded as video and delivered on a variety of devices which would allow for authentic bushfire simulations to be included in a computer game.

Few mobile devices can run high-end 3D games. Even fewer of these are location enabled. After researching possible applications *7scenes* was identified as a possible application development tool. It has an excellent editor for location based learning and games that can be delivered on a tablet device like the *iPad 3*. It is an application available at *7scenes.com* that requires no scripting or coding to develop a game. It is free to use in a simplified version of the commercial application. Scenes can be created and then made available on the web at the *7scenes* website. The GPS in the *iPad* is used to locate the player whose location is marked on a Google Map on the device's screen. The *iPad* can display animated visualisations of bushfires made in *Crysis Wars*. The prototype product that was developed for this research: CODE RED: MOBILE *7scenes* on the *iPad 3* displays movies of bushfire scenes created in *Crysis Wars* and other graphics within a location based framework. It does not allow one to play inside a 3D scene, as can be done in a PC 3D game like *Crysis Wars*. However one can view a movie of a 3D scene at a location in the real world using a movie enabled mobile device like the *iPad 3*. CODE RED: MOBILE was developed as a Live/Synthetic mobile test bed, that can be viewed with an *iPhone*, *iPad*, *iPad 3* (apple.com) or *Android* (google.com) devices.

Chapter 3

Cognitive Science and Conversation Theory inform Pedagogy

3 Chapter overview

The relationship is introduced, of brain anatomy to mental function and the role of the hippocampus to form an egocentric mental framework that records a short term memory. Grid cells assist in the formation of long term allocentric memories. These memories are a god-like overview or schema, where egocentric memories are put together with ideas, and locations of iconic objects. These memorised schema or allocentric memories are used by the working memory to understand and solve problems. Conversation Theory is learning as a conversation between ideas, and between machines operating with an underlying schema of human ideas. These principles from cognitive science and conversation theory, together with scaffolded constructivism form a pedagogy for mobile learning.

3.1 Cognitive Science

3.1.1 Brain anatomy and mental function

Thagard, in the *The Stanford Encyclopedia of Philosophy* (2012) defined Cognitive Science thus: ‘...*the interdisciplinary study of mind and intelligence, embracing philosophy, psychology, artificial intelligence, neuroscience, linguistics, and anthropology.*’ It elucidates the relationships between brain anatomy and mental function with the aim of understanding how animals and humans think. Originally understanding of diseases of the mind or brain was made by correlating changes in behavior with observed damage to sections of the brain.

In 1861 Paul Broca (Dronkers *et al.* 2007) dissected the brains of two patients who had lost the power of speech. He found damage to what is now called Broca's area of the brain. He inferred that this area of the brain controlled, in some way, the production of speech. This was the first example of determining functions of anatomical areas of the brain by correlating the location of lesions, or damage to areas of the brain, to changes in behaviour.

In more recent times, probes have been inserted into parts of a laboratory rat's brain to detect electrical activity and this correlated with cognitive function.

Seiji Ogawa's group at Bell Laboratories (Ogawa *et al.* 1990) discovered that brighter areas on functional magnetic resonance imaging (fMRI) pictures revealed where oxygenation levels were higher. These were areas of the brain that were active and thus using more blood. This enabled the non-intrusive detection of brain activity for real time study of cognitive activity and function. Human subjects could be tested for the anatomical location of aspects of cognition.

Understanding the context of a problematic event is part of the process of preparing a model in the mind ready for decision making and managing courses of action. Experimenting with rats has given us some idea of how this happens.

Figure 3.1: Hippocampus of the human brain. The entorhinal cortex is contained within the parahippocampal gyrus. CA1-CA4 are regions of the hippocampus (annotated by author).

(Source: Image by Frank Gaillard Designs. Image made available under GNU_Free_Documentation_License)

Tolman (1948) studied how rats learned to navigate mazes. He concluded that in the process of discovering a new place they must form a mental model or mental representation of their environment. This model he termed the ‘cognitive map’. Figure 3.1 illustrates the anatomy of the human hippocampus. O’Keefe and Nadel (1978 p. 1) described egocentric spaces as *‘spaces centred on the eye, the head, and the body, all of which can be subsumed under the heading of egocentric space’*. They proposed that the hippocampal⁴ area of the brain provides the spatial framework within which experiences of events and entities are understood. O’Keefe (1976) discovered place cells in the hippocampus of the rat brain. Place cells in the hippocampus

⁴ An area of cerebral cortex that forms a ridge in the floor of the lateral ventricle of the brain, which in cross section has the shape of a sea horse. It functions as part of the limbic system. [Collins English Dictionary – Complete and Unabridged](http://www.thefreedictionary.com/hippocampus) © HarperCollins Publishers 1991, 1994, 1998, 2000, 2003, <http://www.thefreedictionary.com/hippocampus>. Viewed, 13 January, 2013.

record short term memories of where the rat has been. This process generates an egocentric map (Hermer and Spelke 1994; Hermer and Spelke 1996). The egocentric map is created using place cells, which record the direction of each straight lined segment (or vector) that a rat walks within the experimental space.

Mittelstaedt and Mittelstaedt (2001) reported humans use substratal and inertial ideothesis to remember paths they had walked without vision. Substratal ideothesis relies on proprioceptive sensations of movements in joints and muscles. Inertial ideothesis is where movements are sensed by the vestibular system of the inner ear (see Figure 3.2).

Figure 3.2: The human vestibular organ. The 3 semi-circular canals sense rotations of the head. The utricle senses combinations of left and right and backwards and forwards movements, and the saccule up and down movements. (Source: http://en.wikipedia.org/wiki/Vestibular_system)

3.1.2 Grid Cells

Human knowledge of where they are and have been, sensed by the vestibular organ and other senses, must necessarily be recorded by some means. Human subjects were examined for evidence of grid cells by Doeller *et al.* (2010). For the experiment, using a game like scene on a computer, the wall of the virtual space was cylindrical, and had a picture of distant mountains on the this wall, for use in orientation. The human subjects had to collect items on the virtual floor and later replace them at the remembered location. They found that a fMRI could detect a sinusoidal signal (Doeller *et al.* 2010 p. 658) from the left

and right entorhinal cortex as the human subjects traversed the virtual space. The signal was more reliably detected in the left entorhinal cortex.

Doeller *et al.* (2010) found that the 42 male participants used in their experiment showed different orientations for the pattern. As the human subject walked forward (virtually) in the scene along any one of the three axes, proceeding from any one of the grid points, there was a stronger electrical signal than between the three axes (Doeller *et al.* 2010 pp. 657-658). That is, a stronger signal occurred at a periodic angular interval of sixty degrees, thus showing the existence of stronger brain signals when the player walked along any of the three grid axes (see Figure 3.3).

Figure 3.3: **a** shows a view of the Virtual Reality scene from above with the track of one of the participant's as a black line and below the forward looking view. In **b** a grid cell is illustrated showing a sector shaded in red that aligns with a participant's running direction as revealed by the fMRI scan of the entorhinal cortex. In **c** the directions of travel in the virtual scene that show greater activation coincide with the pattern of 3 axes. The fMRI trace of the human entorhinal cortex whilst the participant moves in a virtual reality scene shows periodicity at 60° in **d**. PubMed Commons, PMC3173857. (Source: Doeller *et al.* 2010 p. 658)

When the players moved faster the responses were stronger than when moving at a slower pace. Players having a better memory about the locations of objects in the game showed stronger coherence of potential grid orientations in the right entorhinal cortex (see Figure 3.4 for location of entorhinal cortex), indicating that greater activation could predict better memory performance (Doeller *et al.* 2010 p. 658-659).

Figure 3.4: Medial section of human brain showing location of entorhinal cortex. (Source: Hagman *et al.* 2008. Image: Creative Commons Attribution 2.5 Generic license)

Areas of the brain which provide functions for autobiographical memory⁵ and imagery also showed the 60 degree periodicity (Doeller *et al.* 2010). These areas perhaps append non-spatial information to the temporal and spatial context derived from the grid cells in the right entorhinal cortex. These experimental results provide evidence that humans do have a grid cell system similar to the well-studied rats, for navigation and for creating spatio-temporal memories of place and context (Doeller *et al.* 2010 p.659-670).

3.1.3 Egocentric and allocentric maps

Klatsky (1998 p. 2) stated that:

‘in an egocentric reference frame, locations are represented with respect to the particular perspective of a perceiver, whereas an allocentric

⁵ Memories of experiences.

reference frame locates points within a framework external to the holder of the representation and independent of his or her position.'

The allocentric map records the context of the environment the animal or human occupies, with boundaries, barriers, spaces and objects. These memories of objects or entities are linked in the mind to associated physical and affective memories (Hartley *et al.* 2006). In addition place cells in rats and presumably humans, record slope being traversed and thus vertical movement is mapped (Jeffery *et al.* 2006). The egocentric and allocentric maps for rats and humans record information about height and inclination thus these memories are spatial and in 3D. The grid cells provide a hexagonal grid system for the recording of movements and the mapping of places of interest by the place cells.

In summary the place cells in the hippocampus hold the map of an environment in the memory, the cells firing as the rat moves about the space and as it reaches locations it has been at before. The grid cells in the entorhinal cortex ⁶ (see Figure 3.4) record the rat's movements and keep track of moment to moment location. The recording of spatial information with the grid cells enables rats to do path integration, which means if a rat leaves its rat hole and wanders about a room in the dark, that it can run straight back to its rat hole. Doeller *et al.* (2010) showed that humans probably used the same system to find where they had found objects in a virtual room.

The egocentric map places the animal or human at the centre and is used in exploring and learning a new place in real time. In a sense the creature or human remains at the centre of the map while the environment moves past, whether translating or rotating.

⁶ 'The entorhinal cortex (EC) is located in the medial temporal lobe and functions as a hub in a widespread network for memory and navigation', viewed 30 June 2013, http://www.princeton.edu/~achaney/tmve/wiki100k/docs/Entorhinal_cortex.html.

The allocentric map stays still whilst the entity or creature moves about rotating and translating. An allocentric map is sometimes referred to as a godlike view of a scene or event. It is like a view from above, or a map that shows the relationship of entities to one another. Egocentric explorations recorded in the short term memory are integrated into an allocentric map in the long term memory. The allocentric map can be regarded as a cognitive map or mental model. Thus the cognitive map or allocentric map is not merely about place but about the relationships of objects and their properties including their temporal existence, that is, when they appear, change, or disappear.

Declarative memories can be retold with words and are either episodic memories, which are episodes from one's life; or semantic, which is general, learned knowledge (Buzsáki 2006 p. 209-210). Both episodic and semantic memories are available to the conscious mind. These types of memory depend on the hippocampal-entorhinal system. Procedural memories which include physical skills operate subconsciously, as do emotions and habits. These memories depend on a range of areas of the brain, including the cerebellum, striatum and amygdala. Buzsáki proposed that (2006 p. 333): '*episodic and semantic memory representations may have evolved from mechanisms serving dead-reckoning and map-based navigation*'.

Touretzky and Redish (1996) cited by Klatsky (1998 p.8-9) proposed that there are five components to allocentric memories or mappings- 1) *visual-sensory component* that integrates egocentric distance and bearing, i.e. positions of objects, with information about the object, 2) *head direction component*, 3) *path integration*, 4) *local view component* i.e distance and bearing but from the allocentric reference point, 5) *place code component* which combines local view and visual sensory components. This is instantiated as a specific set of place cells that fire when the animal is at a location in a space.

Allocentric and egocentric memory capabilities can vary between individuals. This tallies with subjects with better memories of locations in a virtual scene (Doeller *et al.* 2010 p. 658-659) having a stronger coherence of potential grid orientations. Variation in memory was also found by Gramann *et al.* (2009) who conducted an experiment where subjects watched a virtual walk through a tunnel on a computer screen. Responses of subjects at the end of the experiment showed that some members of the group only knew their last heading direction as they left the virtual tunnel. Other subjects showed that they added, and retained, each new heading, to the previous heading, starting from the initial heading at the start of the experiment. Gramann *et al.* (2009) showed that the subjects who only had retained the last heading at the end of the tunnel were using egocentric navigation whereas the other subjects had an allocentric memory of the entire journey with the various headings encountered as part of their 3D memory of the tunnel. The better navigators were in the allocentric group and tended to be male.

Navigation is a form of decision making about a journey and utilises egocentric mapping for orienting and discovering a place whereas allocentric maps provide a memorised map of known areas (Touretzky and Redish (1996), Klatsky (1998 p.8-9)). The first is a blank map being drafted; the second a pre-formed map ready for use. Entities' locations are memorized together with their attributes. As we navigate we remember the locations of objects, what they are and whether they are useful, dangerous or neutral; whether they block our way or whether there is a route around them. The allocentric map is like a topographic map, providing information that is not just two-dimensional, but about the third dimension as well. The fundamental skills of cognition involved in this are the same skills needed for placing events or abstract entities into a context so that they become allocentric memories. In other words mapping places is analogous to mapping entities in a context, both are analogous to learning about places or learning about entities in a context. Each creates mental models or cognitive maps of a place, an event or an item of knowledge.

The process of learning is the creation of a new mental model or cognitive map as well as the updating of old mental models or cognitive maps with new information. Each person possesses their own set of cognitive maps, which change as they integrate new experiences and knowledge. This learning is stored in such a way that it is accessible for amendment and decision-making. When decisions have to be made our purpose chooses the problems we feel we must confront and the decisions we will take. Our purpose determines a chain of events that we can put into action that will prospectively cause the problem to be solved. The problem itself may be a purely physical cause resulting from the Universe's machinations with a very long, complex causal chain running since the Big Bang or the cause may result from another person's self interested purpose.

3.1.4 Mental models

Mental models are a framework, which makes the difficult and obscure more accessible to our relatively limited conscious minds. They are a simplified representation of ideas, entities and events created by either observing or 'playing with' the real world or abstract concepts, and representing them in a transformed, simplified form in the memory. Later we can call on this mental model lodged in the memory to assist with understanding related or similar events in the observed world. Some kind of simplified representation of these memories in the mind seems to assist and be associated with the means of the retrieval of memories about entities and events.

In a literature review of how people infer and mentally model how mechanisms work Hegarty (2004) explained that there are two, generally used meanings of mental model: one a model of the brain's processes and anatomy involved in understanding reasoning and for predicting a physical system's behaviour; and the second (ibid p. 280). *'The process referred to as running a "mental model" of a mechanical system'*. Thus, a mental model can be a model of how the brain thinks, or a model of the causes and effects of a

bushfire, a kind of a virtual version of a physical model of the bushfire in the mind. In this research the latter is the main use of the term mental model, so generally speaking an interactive memory or virtual model of an event or mechanism.

3.1.5. Working memory

Working memory was described by Baddeley (2002) as having two main channels or buffers: verbal and visuo-spatial and introduced the concept of an episodic buffer (working memory) that holds thoughts in mind for a short while. Sims and Hegarty (1997) found that adding additional visuo-spatial tasks to the working memory or episodic buffer interferes more with mechanical reasoning than do verbal tasks. Thus we can infer that mechanical reasoning is at least partially dependant on the visuo-spatial channel or buffer. Thus if we are trying to understand a mechanical system we should preferably hear about it rather read about it through annotations.

Though young adults can hold four items in working memory (Cowan 2000), one must consider that people may not be young adults. Although we are limited to about four items in the working memory, we can be assisted by off-loading some of the memory required to artefacts. Artefacts may be maps, visualisations, notes, sketches and models. These can be examined visually and manipulated manually. If they are accompanied by narration or text these can be listened to or read. Maps and visualisations developed as part of the evaluation prototype for this research project are artefacts that assist in learning about bushfires and making decisions about them.

3.2 Conversation Theory for a mobile exercise

CODE RED: MOBILE uses the *7scenes* application delivered on the *iPad 3*, to provide a game like framework and to mediate ‘conversations’ between

participants, and artefacts such as maps, and with information in a range of forms, including visualisations of a simulated bushfire emergency.

A literature review by Naismith *et al.* (2004) proposed that conversation theory (Pask 1976, 1992, Laurillard 2002) is a useful theoretical basis for the design and analysis of mobile games.

Naismith *et al.* (2004 p. 15) summarising Pask (1976) noted:

‘...conversation theory (Pask 1976)...describes learning in terms of conversations between different systems of knowledge. Pask was careful not to make any distinction between people and interactive systems such as computers, with the great advantage that the theory can be applied equally to human teachers and learners, or to technology-based teaching or learning support systems.’

A human being’s system of knowledge and a computer’s system of knowledge can thus be mutually intelligible or at least exchangeable.

Pask (1992) suggested that virtual reality should be employed to make the (ibid Introduction sect 20): *‘otherwise incomprehensible clear’*. This was written in 1992 and perhaps he might now advocate the employment of computer and mobile games to visualise and learn about the *‘otherwise incomprehensible’*.

A cognitive artefact, in the form of media about a bushfire can create a conversation with a learner or participant in a mobile exercise only if the material is presented in such a way that this conversation can develop with ease. This will then lead to learning. The field of pedagogy deals with ways of presenting knowledge such that it is accessible to a wide range of people.

3.3 Pedagogy

An artefact for learning, navigating or decision making like a map or visualisation must be designed and delivered in such a manner that it is

willingly absorbed, understood and utilized. Delivery is a matter of education and in particular pedagogy, the means of best transmitting ideas and data, such that it is learnt by the recipient.

Paidagögos in ancient greek was a term for a male slave who accompanied boys to school and who also attended to their moral education. *Didáskalos* were the subject teachers at the school. The *paidagögos* sat in the school with their charge (Smith 2012). The *pedagogues* were concerned with the boys' behaviour and relationships to society and *didactics* their learning of knowledge. Overtime these meanings changed. The Concise Oxford Dictionary, Fourth Edition, (1950) defined pedagogy as '*the science of teaching*' and didactics, '*meant to instruct, having the manner of a teacher*'. It is curious that pedagogy became about how to teach rather than how to live or behave well, and a didactic, not a subject teacher, but one who is like a teacher, a somewhat derogatory meaning.

Pedagogy for mobile learning could well utilize the original greek meaning of a helper and social facilitator as mobile devices accompany the user. It can provide information about location and context, and give hints and advice on how to use the device and its applications. The mobile device can also enable online social interaction. The mobile device is like the *paidagögos* who accompanied, mentored and assisted the learner. The mobile as *paidagögos* or mentor must still heed the methods of learning. Conversation theory describes the interactions of machine and human, and other entities, for learning and understanding. Pedagogy studies the best ways of organising these interactions.

3.3.1 Constructivism

The earlier sections on Cognitive Science and Conversation Theory developed ideas that assist in the design of a mobile training exercise to deliver visualisations for participants learning about bushfires. Bruner (1973) propounded the basic ideas of Constructivist learning. Kearsley (2012 section

Principles) citing Bruner (1960, 1966, 1973, 1983, 1986, 1990, 1996)

summarised his principles as:

- “1. Instruction must be concerned with the experiences and contexts that make the student willing and able to learn (readiness).*
- 2. Instruction must be structured so that it can be easily grasped by the student (spiral organization).*
- 3. Instruction should be designed to facilitate extrapolation and or fill in the gaps (going beyond the information given)”.*

In response to Bruner’s ideas on constructivist learning, Kirschner *et al.*

(2006 p. 3) commented that:

“Any instructional procedure that ignores the structures that constitute human cognitive architecture is not likely to be effective. Minimally guided instruction appears to proceed with no reference to the characteristics of working memory, long-term memory or the intricate relation between them.”

Thus we should take notice of the limits of working memory and what cognitive science and pedagogy informs us on the construction of memories of place and incident. Approaches like constructivism that emphasise discovery learning do not always work well (Kirschner *et al.* 2006). Learning must be scaffolded by the teacher so that it is delivered in bite sized pieces.

3.3.2 Scaffolding

Scaffolding is assistance given to learners for a learning activity by structuring the information and by problematising it (Andrews and Haythornthwaite (2007), citing Reiser (2004)). Problematising directs learners to issues and tasks that will assist in understanding an issue. Direction in solving problems can be given by guiding students to information, suggesting how to record data, and how to juxtapose, rank and weight their competing hypotheses.

Scaffolding and mental models are also described as chunking information (Miller 1956). These ideas on constructivist learning using scaffolding, otherwise called chunking, are relevant to adult groups with diverse learning abilities. CODE RED: MOBILE features learning using visualisations, delivered as movies and static images that scaffold information about a running fire.

The research for CODE RED: MOBILE has focused on cognitive and conversation theory, and constructivism with scaffolding as the substrate for the CODE RED: MOBILE package, which included the mobile training game and the learning and tracking experiments that pertained to it.

3.4 Chapter summary

In this chapter, key notions of cognitive science, Conversation Theory and pedagogy were examined.

The development of mental models or cognitive maps was examined in detail in this chapter, including the role place and grid cells have in laying down egocentric and allocentric memories. These create and record a map in the mind with iconic features marked as landmarks. This laying down of a memory of a place is paralleled by the laying down of memories of knowledge. The anatomy of the brain was discussed in relation to functions related to navigation, learning and decision making. The limitations of working memory lead to ideas of chunking and scaffolding information for a scenario training exercise.

Conversation Theory was introduced as a basis of developing new knowledge by sharing and discussion. This can also be a sharing with a machine or even between machines. One or more people and, or machines in a discussion can exchange information and the combination of their opinions, data, mappings, evidence, conceptualizations combine to form a new item of knowledge.

Knowledge or events can be broken down into related chunks linked by cause and processes. This structure is a linked set of ideas or a schema so that it is

in a form ready to use as a scaffolded piece of learning or a framework for developing training exercises.

Pedagogy was examined in relation to mobile learning. The conclusion was that constructivism with scaffolding or chunking of knowledge is the pedagogical vehicle by which learning in a field exercise may be appropriately delivered.

Mental models of a place can be learned from someone in a conversation, in Pask's terms, that delivers the mental model in the form of story, a map drawn in the sand, or a text message on a mobile phone. Place can also be understood by maps on mobile devices or models at a tourist information site. The next chapter examines learning at, and about a place.

CHAPTER 4

Learning where we are

4 Chapter overview

In this chapter a short history is presented of the development of mobile devices suitable for delivering learning. Ubiquitous learning, e-learning and mobile learning and the evolution of these terms is discussed. Location based services and location based services and games are introduced. Mobile games and training involve participants moving through open spaces, and these movements can be examined with geospatial analysis. Heatmaps, space-time cube analysis using *Geotime 5.3*, and fractal analysis are introduced.

4.1 Mobile devices for learning

Figure 4.1: The *Dynabook* as imagined by Alan Kay (Kay 1972 p. 1)

Alan Kay (1972 p.1):

‘Zap! With a beautiful flash and appropriate noise, Jimmy’s spaceship disintegrated; Beth had won Spacewar again. The nine- year- olds were lying on the grass of a park near their home, their dynabooks hooked

together to allow each of them a viewscreen into the spaceworld where Beth's ship was now floating triumphantly alone.'

Alan Kay's (1972) prescient proposal for the *Dynabook* (Figure 4.1) was a mobile computer for learning that could be networked and was simple enough for children to operate. He advocated constructivism as the educational theory most appropriate for its use in learning (Bruner 1973; Kearsley 2012). Pask's Conversation Theory is echoed in the words of Seymore Papert and Cynthia Solomon (1971 p.1):

'...the transaction between the kid and the computer will be some kind of "conversation" or "questions and answers" in words or numbers.'

In 1991 The Apple Classrooms of Tomorrow together with the Orange Grove Middle School in Arizona, studied a valley measuring its temperature and other environmental variables. This data was shared in a Local and Wide Area Network (LAN and WAN) using Macintosh computers (apple.com) and cellular phones. The project was called '*Coyotes in the Wild*' (Grant 1993).

Figure 4.2: *HandLeR* concept on a *Fujitsu Stylistic* tablet computer. (Source: Sharples 2007; <http://www.slideshare.net/sharplem/history-of-mobile-learning-mlearn-2007-doctoral-consortium-oct-2007?nomobile=true>)

Mike Sharples (2000) using these and other concepts (Kay 1972; Papert and Solomon 1971; Pask 1976; Bruner 1973) developed the *HandLeR* prototype for children age 7-11. The prototype on the *Fujitsu Stylistic* tablet computer which weighed 1.5 kg is displayed in Figure 4.2. *HandLeR* was designed to be a software environment suitable for a variety of platforms. The most important design feature was that the system should support learning in various contexts and over a long period of time (ibid p.11).

The mLearn series of conferences began in 2002 initiated by Mike Sharples. In 1996 the *Palm Pilot* PDA (Personal Digital Assistant) (Size: 120 mm x 80mm x 18 mm. Weight: 160 grams.) was introduced by SRI International (Niccolai & Gohring 2010). The Consortium, a non-profit education foundation in Concord Massachusetts, provided 3 local High Schools with 3000 *Palm IIIxe* (Size: 8.1 cm x 12 cm 1.8 cm. Weight: 170 g.). 55 teachers volunteered to use them with their students. A major problem was the glass screens often broke in the students' school bags.

Figure 4.3: The *Savannah* learning game on *HP iPaq*. (Source: Benford *et al.* 2004)

The *Palm IIIxe* had 12 or more probes which could for example measure temperature, pH, and voltage (DiChristiana 2000). They were used at one of the schools to study the water at the Pickle Ponds in Hudson Massachusetts.

iPaqs (Figure 4.3) were also used for the innovative Savannah *mscape* activity (Benford *et al.*2004).

Holzinger *et al.* 2005 advocated the benefits of learning with a mobile phone whilst lamenting the small size and poor resolution of the mobile phone screen, limited processing power, little standardisation of input systems and a wide diversity of operating systems.

The first smartphone was sold to the public by IBM in 1993 (Figure 4.4). It had applications like a clock and calendar and could send and receive email and Fax. It had a touch screen and a stylus. In 1996 Nokia released the Nokia 9000 (<http://itlog.net/content/first-smartphone>) and termed it the ‘Communicator’. In 2002 Microsoft offered an operating system for the mobile phone called the ‘Microsoft Windows Powered Smartphone 2002’.

Figure 4.4: 1993, *IBM Simon*, the first smartphone. Size: 173 mm x 64x 38 mm. Weight 379 g. (Source: <http://www.howtogeek.com/trivia/what-was-the-first-smartphone/>, viewed 22 June 2013)

The *iPhone 3G* (Figure 4.7) was released in 2008 with CPU: *Samsung S3C6400* (ARM11 core), 3.5 inch multi-touch screen (apple-history 2012).

Android Incorporated was established in 2003 and taken over by *Google* in 2004 (visual.ly 2013). The first *Android* operated phone was the *HTC Dream* (Figure 4.5). *Android* is the operating system for a range of smartphones (current in 2013) including the *HTC 1*, *Samsung Galaxy S4*, *Galaxy Note II*, *HTC First* and *Nexus 4* (TechnoBuffalo 2013).

Figure 4.5: To the left is the *HTC Dream* with *Android* operating system. Size 117.7 mm x 55.7 mm x 17.1 mm. Weight: 158 g. (Source: <http://www.gsmarena.com/htc_dream-2665.php>, viewed 22 June 2013). To the right is the *iPhone 3G*. Size: 115.5 mm x 62.1 mm x 12.3 mm. Weight: 133 g. (Source: <http://www.gsmarena.com/apple_iphone_3g-pictures-2424.php>, viewed 22 June 2013)

Figure 4.6: *Samsung Note II*. Size: 80.5 x 151.1 x 9.4 mm. Weight: 182.5g. (Source: <http://www.samsung.com/global/microsite/galaxynote/note2/> viewed 27 February 2014)

An adapted version of the *Samsung Note II* (Figure 4.6) was issued to US Army Rangers and soldiers of the 10th Mountain Division in 2013 (Dixon & Henning 2013). It is used with the *Nett Warrior* system.

Tablets are a scaled down version of laptop that generally have the capabilities of a smartphone. Microsoft (msdn 2013) released the *Tablet PC* in

2002 and described it as: ‘a fully-functional personal computer running Microsoft® Windows® XP that is geared for pen-enabled, handwriting-enabled, and speech-enabled applications’.

The *iPad* (Figure 4.7) was released in 2010 and in 2012 was in its 4th iteration and had a smaller version the *iPad mini* (apple-history 2012).

Figure 4.7: 4th generation *iPad*. Size: 241 mm x 186 mm x 9.4 mm. Weight: Wi-Fi 652 g and Wi-Fi Cellular 662 g. *iPad mini* in front. Size: 200 mm x 134.7 x 7.2 mm. Weight: Wi-Fi 308 g and Wi-Fi Cellular 312 g. (Source: <http://reviews.cnet.com/ipad/pictures/2300-31747_7-10014376-3.html>, viewed 22 June 2013)

Franklin (2013) provided a list of the best currently available tablets as at April 15, 2013. These were: *Apple iPad* (4th generation) considered the best tablet in this review, *Google Nexus 7*, the best small tablet, *Amazon Kindle Fire* best for media consumption, *Google Nexus 10* the most powerful *Android* with better screen than the *iPad*, *Samsung Galaxy Note 8* expensive but with good stylus, *Microsoft Surface with Windows 8 Pro* expensive but good for work applications.

However the hyperbole of advertisers and media pundits has to be balanced with considerations of the purposes and practical use of such devices in the classroom, the workplace and in the field. A trial using 75 *iPad* in 3 schools in

New South Wales, Australia in 2012 produced the following conclusions (Goodwin 2012 p. 13):

‘Developers need to design apps that are vastly different to the design of ‘skill-and-drill’ software that currently dominates much of the educational market.’

The *Ipad* in classroom practice is generally being used for tasks that can be done in conventional ways. Goodwin (2012) asserted that tools should be developed that would further enable creativity and provide ways to make or employ dynamic representations or simulations for learning.

This survey of the development of mobile devices is complemented in the next section with an account of the parallel development of learning practices afforded by mobile computing. Many of the provided examples exploit the interactivity of the devices providing embodied learning and utilising dynamic representations.

4.2 Learning in the field

Weiser advocated Ubiquitous computing but lamented that in 1992 the existing computers (1993 p.2): *‘cannot produce a simulation of significant verisimilitude at reasonable cost’* indeed (in 1993) *‘at any cost’*. He was referring to Virtual Reality applications that were then not convincingly realistic.

An early example of a reasonably satisfactory example was *Exploratorium*, a museum guide. The location of the user could be detected and information about the ecology of an outdoor area delivered to the user on a handheld networked device (Roschelle & Pea, 2002). This relates the PDA and the person holding it to a position in an outdoor location. This position then determines the information that will be received. It is a Location Based Service for learning.

Learning in the field whilst moving and learning with mobile devices are subsumed by the term *mobile learning*. Quinn (2000 sect 1) '*Just what is mobile elearning (sic) ? It's elearning through mobile computational devices: Palms, Windows CE machines, even your digital cell phone. Let's call them information appliances (IAs)*'. Sharma and Kitchens defined mobile learning as (2004 p.205): '*...learning supported by mobile devices, ubiquitous communications and intelligent user interfaces*'. Sharples *et al.* (2005) utilised the term m-learning describing it as the use of mobile and other devices to remotely access learning and teaching materials. M-learning has been defined by Harris (2001) cited by Kambourakis, Kontoni, and Sapounas (2004 p.1) as: '*The point at which mobile computing and e-Learning intersect to produce an anytime, anywhere learning experience*'.

Mobile learning has been viewed as simply handheld learning (Caudill, 2007) but also it can be regarded as mobile learners i.e. the learners can access learning modules remotely (Traxler 2007). In this second view distance learning can be construed as mobile learning and it is the wifi, Internet or telephony network that enables mobile learning (Nyiri, 2002).

Caudill (2007 p.7) quoted 'Laouris and Eteokleous (2005), citing Pinkwert, *et al.* (2003) as defining e-learning as '*learning supported by digital 'electronic' tools and media.*' Caudill also cited Ramshirish and Singh (2006) who defined e-learning (2007 p.2) as: '*... essentially education via an electronic network in which content is transferred via the Internet, intranet, extranet, audio/ video tapes, satellite television, and CD-ROMs*'. Thus in this view mobile, ubiquitous and pervasive learning comes under the umbrella of e-learning.

The m-learning environment is a provider of special advantages for learning as distinct from e-learning (Caudill (2007). M-learning did not require the learner to be tethered through wires to static devices. The mobile devices were light weight and portable. Thus m-learning, although a manifestation of the delivery, may in fact provide special advantages that e-learning as such does not, at least in the traditional sense.

Pervasive learning has been described by Thomas (2005) as learning that utilises omnipresent technology. It especially involves *community* connections and roles, the *autonomy* of the learner, the *locationality* of the learning, in that it can occur anywhere and the *relationality* to the learning which is personal and therefore more meaningful to the individual. Mobile learning then is an overarching term which includes mobile and pervasive learning. Mobile and pervasive or ubiquitous learning appear to be manifestations of the same type of learning delivery.

Theories of mobile learning are lacking (Schuler 2009) and this has frustrated the development of new pedagogies and the design of applications suitable for learning. In addition research is needed into the benefits and affordances of the devices and the disadvantages of the smaller screen and the distractions of the mobile device and its real world settings. Research is needed into how organisations can utilise, adopt and adapt such devices and methods of learning (ibid).

In *A Model for Framing Mobile Learning* Marguerite Koole (2009) has proposed some advantages for mobile learning in that it operates wirelessly and provides access to information whilst at any location. Learning in a context provides authentic local based information making memorisation easier. This lowering of cognitive load and new patterns of presentation can further assist learners to remember and transfer new knowledge.

Transformations afforded by mobile devices is thus not merely of the new relationship to local and distant contexts for learning provided by mobile devices, but also that of sharing learning and its products, decisions and actions, with others (Traxler 2007).

In this chapter, to this point, we have looked at Location Based Services that deliver content wirelessly at a location (Schilling *et al.* 2005) and in a context (Nivala & Sarjakoski 2003). This may be for entertainment or tourism purposes. Glossy technology and the *gee whiz* attitude (Cartwright & Hunter

(2001 p.29) should be avoided to make sure the technology delivers value that exceeds traditional methods.

Subjects in an experiment favoured schematic maps rather than realistic images (Plesa & Cartwright 2007) and Schilling *et al.* (2005) found that viewers preferred a flying overhead view of 3D scenes and looking slightly down. Also that paper maps were preferred to 3D maps especially on mobile devices with screens that suffered from glare in full sunlight.

4.2.1 Location Based Services (LBS) for tourism

LBS can be used for tourism services (Schilling *et al.* 2005) and social communications D' Orazio (2012) as well as learning. They have also been developed for geo-enabled knowledge.

The Webpark Project was a location based service delivered by a mobile information system for geo-enabled knowledge and was studied by Edwardes *et al.* (2005). The LBS considered two contexts: that of the user; and that of the pertinent phenomena. These LBS are differentiated in MacEachren's terms (1994) as discrete and abrupt. This can be a point of interest (POI) and real time event; or discrete and smooth such as deer observations. They may also be continuous phenomena such as the density of vegetation types or animal distributions. The database for WebPark linked locations to multimedia content classified by location and by ontological relationships to other content.

Key conclusions made by Edwardes *et al.* (2005) were that often data format was not well suited to location based services and needed transformation; that much data was not located at points; and finally that geographic information about spatial and temporal relationships needed to be preserved.

It is argued that these conclusions also apply to this research in terms of placing a dynamic bushfire moving over a terrain after a wind change. The bushfire also varies in behaviour over its extent and it is most dangerous at the front and least at already burnt areas. It is a continuous phenomenon,

though in some ways there are abrupt changes internally and at edges. These changes are both spatial and temporal. Spot fires add another level of difficulty being either abrupt or discrete initially, but developing later when they merge into a continuous fire phenomenon.

Visitor use of WebPark in the Texel Dunes National Park (the Netherlands) and the Swiss National Park in eastern Switzerland were studied by Dias (2007). He described the application as a context-aware location-based service. The application WebPark was trialed on a PDA supplied to tourists who were divided into 4 groups. These groups were the *No info* group (which was the control); the *Paper booklet* group; the *Digital information* (used a mobile device); and the *Context-aware information* group (the same as *digital information*, but location based services were triggered by GPS). 400 visitors were tested after visits to Texel Dunes National Park.

Participants' opinions from the location-based services group where information at a location was delivered automatically using GPS location and the group that had access to digital information but they had to access it on the device themselves having found what location it was about.

The location based information group found the application was more useful. Both groups found the system 'fun to use (p.178) but the location- based found it 'enjoyable'. This hedonic (pleasure) appreciation of the technology is relevant to an application that is used by holidaymakers in National Parks. This is somewhat different to a tool used by firefighters for training or an experiment about mobile training that has a more instrumental or utilitarian aspect.

Visitors GPS tracks were recorded and aggregated; and individual tracks compared to this baseline. The number of stops of over 15 seconds in a five metre segment was measured. The *Digital Info* group stopped more often than the *Paper Info* group. The *Digital Info* and *LBS* group walked about the same length of time but the *LBS* group stopped more often. The overall conclusion was that location based information had a significant and positive

effect on visitor behaviours. Significantly less visitors strayed from the path, did not look at a viewpoint or took a shortcut. The visitors were constrained by a fixed track with points of interest along it, however some still strayed.

The firefighter participants in the CODE RED: MOBILE exercise were also tracked with GPS. Analysis of the tracks was undertaken using spatio-temporal techniques including space time cube, heatmaps and Fractal analysis. These are further explained in chapter eight.

These examples of LBS based learning showed that they are useful for the delivery of media at specified locations, assisted with remembering where items or events were located and assisted with passing on information about using the area.

4.2.2 LBS for learning

Stenton *et al.* stated that (2008 p. 3):

‘beyond the research community there are a number of efforts underway to develop services and applications that use or capture context. The initial commercial efforts are fairly basic and focus almost exclusively on physical location and location based services’.

Learning which takes account of context and location may be considered mobile learning. Some applications for learning that take consideration of context are presented next.

A Location Based Service was created at the University of Twente in the Netherlands (Kobben *et al.*, 2007). The application called *FLAVOUR* was implemented for a conference and delegates could access services to find facilities and contact other participants. It used a wireless local area network (WLAN) for detecting the location of users of the system, and delivered maps and mobile applications using cartographically aware database objects.

MoGeo (Mount *et al.* 2006) was an application that worked on a pocket computer with GPS. Internet mapping applications and connections allowed

for server- side delivery and manipulation and interrogation of geospatial information. Exercises and lessons for students were given in the field and the classroom about Geographical Information Science (GIS). In the field application using the GPS data detected if the student was within range of a pre- recorded location and the pocket computer received media particular to that place from the server via a wi-fi network. The order of ‘triggering’ places was an important part of the learning task and only the correct order was rewarded. In a remote area a laptop server could supply a group of pocket computers with server side data connections.

Mscape was provided free for education purposes, developed by Hewlett-Packard. *Mscape* included an editor, a player and a map maker. It ran on Hewlett Packard iPAQ PDAs as well as some smart phones with inbuilt or *Bluetooth* enabled GPS. Facer *et al.* (2004) described a novel application called *Savannah* for the iPAQ (hp.com) pocket computers used by teams of students to learn about the African savannah. Primary school children played the role of a lion and acquired points as they found food and avoided angry elephants and hunted down prey. As the students entered certain areas their location triggered particular sounds or multimedia. The much-reduced scale of the playground area was a difficulty. With ease, the students understood the game rules featuring behaviour, and also geographical constraints. There were competing realities in that there was no interaction with the real space they were playing in, as there were no rivers, mountain ranges or forest or any objects representing them.

Mscape was an application trialled as the delivery vehicle for the prototype CODE RED: MOBILE. It was subsequently replaced by *7scenes* (7scenes.com). *Mscape* was relatively easy to use and there was a repository of information at the website as well as an active forum, but which has since, ceased, operation. The editing part of the application (on a desktop computer) required a geo-registered image or map. Figure 4.8 shows the *mscape* editor in the background with the base map displaying the test area and a highlighted circular trigger area in a square outline. The script editor is to

the left of centre at the bottom. To the bottom right is the tester application, here overlayed on the editor. The tester shows a game in progress on the desktop computer. A small icon representing the player is in the trigger circle

Figure 4.8: The *Mscape* editor and tester.

and to the left is a view of the screen which opens over the base map area on the mobile device. The screen shows the visualisation of a bushfire made in *Crysis* that would fill the screen of the pocket computer after it is triggered by the player's location. *Crysis* is a video game made by Crytek Frankfurt, Germany and published by Electronic Arts.

Figure 4.9: *Mscape* on *iPaq* shows the imported cadastral map of a rural area with the player location a small icon in the trigger circular area.

Figure 4.9 shows the *iPAQ* screen with the game running and the player icon is centred in the trigger area. This would normally have turned on the animated visualisation but the GPS has been turned off so the visualisation does not display. This was done to enable the viewing of the player icon at the centre of the marked trigger area.

Figure 4.10: *Mescape* on the *iPAQ* displaying an animated bushfire visualisation made in the *Crysis* editor (crytek.com).

In Figure 4.10 the GPS and the player's location has activated the visualisation. This visualisation of a bushfire is a recorded scene from a modified version of *Crysis* (crytek.com). Vegetation and fire and explosions are graphically excellent in the *Crysis* game. However they were reduced in visual quality in the conversion processes for *mescape* on the *iPAQ*.

Mescape on the *Ipaq* PDA could play media from the storage card, or connected by Bluetooth through a mobile phone and use the mobile phone data network, to access and view Web pages. The mobile data network downloading was however costly and the free storage card media was preferable. *Mescape* played *Flash* based video. The interface was suitable for primary school students and thus not difficult for most adults to use.

Mescape was seen as suitable to create a trial location based learning game about bushfires. However development was stopped by Hewlett Packard.

Calvium (<http://www.calvium.com>) continued to develop a version of the application. Calvium has released *Escape from the Tower* for the iPhone (<http://www.calvium.com/apps/towerescapes/>). This is a location based game developed in association with the Tower of London, in London, England. Players help historically famous prisoners escape from the Tower and win virtual money if successful.

Mobile devices are becoming less expensive and more powerful and are often provided with an inbuilt GPS. These devices loaded with carefully crafted *Mobile Learning System* can provide learning in a location-based context. The context can be either virtual and at a small scale in a schoolyard such as for the *Savannah* game or a real context at a historical site where decisions can be made, e.g. *Escape FromThe Tower* (Reid 2010).

4.3 Location based games for learning

Location based services can also deliver information that can be used in various forms of games, in this case games for learning.

Admiraal *et al.* (2009 p. 302) reported that ‘...mobile games... are excellent ways to combine situated, active and constructive learning with fun.’

The game, *Frequency 1550*, was designed with history teachers and coordinated by the Waag Society (www.waag.org). The game players were students from local schools: pre-vocational, upper secondary and pre-university. Students played merchants or beggars and tried to get enough points to become citizens of the city in 1550. After the game, recorded files were collected, and recorded GPS trails of the participants archived. Also, students answered a questionnaire on motivation, and did a test and wrote an essay on medieval Amsterdam.

Results showed that the students were very enthusiastic. They did not engage much in the competitive elements and concentrated rather more on the assessed tasks. The small screen and sun glare made the reading task difficult. Students received information through videos delivering the

narrative or story. The students barely glanced at the video or text information scrolling down quickly to the set work. They thus did not have a grasp of the historical background of the game and did not show much interest in the notion of gaining citizenship. Searching for information on the internet was difficult for those teams who did not know the key words to use.

Games such as this are valuable for learning history in its geographic context. Information provided by visualisations needs to be delivered, such that it must be carefully construed for success in the game.

Route Mate, is a mobile location based route- finding application, using *Android* based mobile phones, for people with intellectual and sensory disabilities (Brown *et al.* 2011). It is designed to develop independent travelling skills. A fundamental consideration was that learning in the real world and time context can compensate for lack of memory skills as well as the prevalence of concrete thinking amongst the clients. Brown *et al.* (2011) citing Gow *et al.* (1990) reported that concrete thinking can be defined as context dependent, generally rule following and where learning is often not readily transferred to new contexts.

Mobile devices can provide access to images, maps, sounds and text related to a location. Brown *et al.* (2011 p.12): '*Systems for new route learning using location based services can be appropriately structured to heavily scaffold the planning of new routes and the first instances of travelling these new routes*'.

Brown (ibid) proposed that too much support leads to a lack of learning and personal cognitive maps are not then constructed by the participant. A game-based approach may lead to the development of personal cognitive maps. The use of a mobile phone with map and GPS allows the person, with help, to plan a route, then rehearse it and finally use it independently. Photographs can be taken along the route and saved to the map on the phone to aid navigation and memory. The in- built compass aids direction finding. They concluded that because the game concentrates on learning a new route rather than just following a guidance system the participants may be more empowered and

benefit in general cognitive skills. *Route Mate* testing involved the participants in planning a route, then doing a practice run and finally independently walking the route they had learned.

4.4 Spatio-Temporal Analysis of movement in games

4.4.1 Heatmaps

Heatmaps have been used to detect patterns of behaviour in computer games. Overlapping and concentrated tracks draw attention to where action is at its fiercest. Heatmaps can be made with Geographical Information Systems.

Figure 4.11: Heatmap of Halo game. Publisher Microsoft Studios, developer Bungie. (Source: <http://halo.bungie.net/online/heatmaps.aspx>, viewed 5 April 2012)

like *ArcMap 10* (esri.com). In Figure 4.11 the locations of player virtual deaths have been displayed as a heatmap with red showing a high concentration of deaths and blue lower concentrations. These are correlated with the weapons that destroyed them, so that players can analyse locations where particular weapons are most effective. The website <http://halo.bungie.net/online/heatmaps.aspx> is no longer being updated.

4.4.2 Space Time Cubes

Torsten Hägerstrand (1916–2004), was a Swedish professor in human geography. His original research was on the effects of emigration to the United States of farmers from the Parish of Asby in Sweden, during the

nineteenth century. He developed a theory of time geography that resulted in his Space Time Cube in the late nineteen sixties (Hägerstrand 1970; Kraak 2003b). This visualised the locations of people or objects as they moved through time and space. *Geotime 5.3* shown in Figure 4.12 is a commercial application based on the Space Time Cube.

Figure 4.12: *Geotime 5.3* in 3D view. The coloured icons represent participants in the CODE RED: MOBILE exercise. The vertically movable slider bar to the left is dragged up or down, showing the icons movements along their GPS tracks. The GPS track is displayed as the pink line on the ground surface. The 3D traces in the space above move through the icon vertically, providing a means of finding the time the participant was at a location. The colour of the icon matches the colour of the time trace.

Geotime 5.3 was used, for this research, to plot the spatio-temporal movements of participants in the CODE RED: MOBILE exercise. The results are in chapter eight.

Figure 4.13: Visualisation of a player's movement in a game of *Pac-Lan* (Coulton *et al.* 2006). Copyright © 2006 Paul Coulton *et al.* Creative Commons Attribution License.

Player behaviour was visualised using a Space Time Cube in a pervasive location based game of *Pac-Lan* (Coulton *et al.* 2006). In Figure 4.13a a visualisation of the spatial movements of a player is shown and in 4.13b the timing of his movements (ibid p.2). Player behaviours were studied in a game with five participants. In one experiment two players who chased the person who played the PAC-LAN role, did so closely, and the other two players did not. One of those who did not follow *Pac-Lan* closely was trying to ambush him and succeeded in doing so.

This research used a similar idea to track each participant in CODE RED: MOBILE, and went a step further, analysing participant's spatio-temporal behaviour in the exercise using, in addition, Fractal Analysis. Fractal analysis is introduced in the next section.

4.4.3 Fractal Analysis

In 1967, it was pointed out by BB Mandelbrot (1967), that the coastline of Britain consists of involved curves, with properties that showed the shape of a small section, is a reduced scale image of the whole coastline. The degree of complication is **D**, or a dimension that is larger than 1 (which is the dimension of a curve). Mandelbrot wrote that (ibid p.1):

'Then, to evaluate the length of a coast between two of its points A and B, one may draw⁷ the shortest inland curve joining A and B while staying within a distance G of the sea.'

Richardson 1961, cited by Mandelbrot (1967 p.2) proposed a formula

$L(G) = F G^{1-D}$, where F is a positive constant prefactor⁸ and D is a second constant, at least equal to unity. This gives a measure of the nature of a frontier between countries or of a coast. $D = 1.00$ is a value for a straight coast, $D = 1.25$ a very tortuous coast like that of south west Britain and $D = 1.13$ is the coast of Australia. These values of D give a measure of the tortuosity of the coast or border and may also be used for GPS tracks. Mandelbrot (p.3) concludes with the comment that '*geographical curves are random, self similar figures of fractional dimension D*'.

Fractal analysis has been used for searching, dispersal, orientation and navigation, especially in animals from insects to whales. Mandelbrot (1983) suggested that fractals would be one way of analysing their tracks and Milne (1997) that tortuosity, in the form of the Fractal Dimension (Fractal D), can

⁷ Using a pair of dividers.

⁸ A coefficient which precedes a given quantity in a mathematical formula.

measure an animal's movements in relationship to environmental and behavioural factors (Nams and Bourgeois 2004).

Milne (1997 p.39):

'Here is the most important point when using fractal geometry to solve problems in wildlife biology: the animal is the caliper⁹. For example, on average, the area of an animal's home range (i.e., its caliper) increases with body mass because larger animals need more food and have to cover more ground to find it.'

Thus the animal's size is related to its range and the affordances in terms of food and shelter of its territory. Peter Turchin (1996) related that though movement of animals are often random, they may sometimes be responding to cues with relatively fixed rules. It would not be possible to determine all the parameters involved when they are responding to these cues, so such movements should be studied stochastically.

Firefighters also respond to such cues, as they look for a fire's edge, or in a training exercise on a mobile device, search for a virtual marker.

A Fractal D score is a measure of the tortuosity of a person or animal's track and can be between 1 and 2. A score of 1 indicates a straight line and a Fractal D of 2 is a line that is an exceedingly tortuous track that fills a plane. The spatial scale of a track reveals the Fractal D at various lengths of movement. Kearns *et al.* (2010 p. 592):

'A person walking down a long corridor has a low Fractal D (it approaches 1.0, i.e. a straight track) at large spatial scales. If they see an interesting sculpture in an alcove, they turn and walk around it, moving in and out to get a closer view. This produces a more tortuous track and a higher Fractal D (perhaps 1.5, i.e. a tortuous track) at this smaller spatial scale of the alcove.'

⁹ In a sense like dividers measuring a coast's length.

Figure 4.14: A wombat's foraging behaviours as spatio-temporal variations with low and high Fractal D scores.

Figure 4.14 shows a track of a hypothetical wombat. The wombat is digging up roots or other food in small patches i.e. at a short spatial scale. This is quite a tortuous track and Fractal D might be something like 1.5. These food rich zones are within the green circled areas. Where the wombat had to walk something like 100 metres over the barren ground the Fractal D might be 1.1, which is a fairly straight track. In the smaller patches, marked by the green circles, it constantly has to turn, this way and that, to find individual roots or bulbs. Sharp bends in the track increases the tortuosity and thus the Fractal D (pers. comm. V. Nams, 30/10/2012). Furthermore tracks that cross themselves can reach scores over 2 thus exceeding the theoretical limit for a fractal.

Fractal D is not independent of spatial scale and scale invariant (Turchin 1996) as some researchers believed. Statistical fractals differ from exact mathematical fractals, in that statistical fractals vary in tortuosity at different spatial scales, whereas mathematical fractals have the same tortuosity at all scales.

Fractals, as seen in the real world, are only imperfectly self similar (Doerr & Doerr 2004). These are statistical fractals and show self similarity only at

some scales. As the Fractal D changes or jumps between scales, these steps are separated by transition zones. This shows some degree of statistical self similarity, but only over a limited range of scales. This existence of stepwise behaviour (changes in fractal dimension when shifting between scales), shows partial self similarity over limited ranges of scales, separated by transition zones.

American Martens displayed changes in Fractal D of their tracks over various spatial scales (Figure 4.15) (Nams and Bourgeois 2004). This provided a method of discovering habitat preferences of the animal. The Fractal D of the American Marten's track increased more slowly above a spatial scale of 3.5m indicating a change in behaviour related to the type of habitat. In this case, Nams and Bourgeois (2004) interpreted this as resulting from the

Figure 4.15: American Marten tracks at various Spatial Scales. A breakpoint can be seen at 3.5m. This shows that the response to the habitat changes at a scale of 3.5 m. and the tortuosity of the animal's track increases less after a scale of 3.5m. © Canadian Science Publishing or its licensors. (Source: Nams and Bourgeois 2004, p. 1743)

trees being at a density of one every 3.5 meters or so. The American Martens went in straight lines generally speaking from one tree to another. They could not account for the changes in Fractal D at scales larger than 3.5 m.

Fritz *et al.* (2003) studied wandering albatross tagged with GPS devices. In Figure 4.16 the Fractal D peaks on the chart are at 0.1 km and at 10 km. These are the transition zones. On the right in Figure 8.29 the individual wandering albatross track for Bird B0402, at a spatial scale of 10, and less, had a zigzag flight.

Figure 4.16: Wandering albatrosses (*Diomedea exulans* flights. The step size corresponds to spatial scale otherwise divider size. Image by permission of the Royal Society. (Source: Fritz *et al.* 2003 p. 1144)

Figure 4.17: Bird B0402. The 2 transitions divide the bird's flight into 3 domains. Image by permission of the Royal Society (Source: Fritz *et al.* 2003, p. 1145)

Domain 1, shown in Figure 4.17, with a mean Fractal D of 1.01 is produced by the dynamic soaring flying style of the albatross. This is a zigzag track at a very small scale but with an overall straight path. Domain 2 is typical of the albatross flight as it reaches areas in the ocean where upwelling currents from the deep ocean hit the continental shelf, bringing nutrient rich deep water to the surface, and providing abundant food for pelagic species like the albatross. They are making turns at a scale in the order of kilometres. In Domain 3 they are flying straight, mostly with the wind on their left side over very long distances of over 75 km making turns at that scale producing a circuit on a near global scale. Here they are travelling with the roaring forties, in the southern hemisphere to the east, then turning anticlockwise to the north, in a huge circuit which then takes them near the equator, and they fly home with the westward wind. If they go north from their home island they go on a huge clockwise circuit that also returns them along the equator to their origin. This results in an efficient expenditure of energy in regard to

the large distances travelled (Alerstam *et al.* 1993, Weimerskirch *et al.* 2000). The charts in Figure 4.17 reveal how Fractal D, and thus the nature of the albatross' flight patterns, can change at various spatial scales in keeping with the bird's intentions or instincts (Fritz *et al.* 2003).

Fractals have also been used to study human spatio-temporal behaviours.

4.4.4 Tracing and tracking human beings

In an investigation of the relationship between Fractal D and the prognosis of dementia for a group of elderly residents in a long term care facility, Kearns *et al.* (2010) found that residents with a high Fractal D score, i.e. tortuous tracks were more likely to have dementia and consequently an increased chance of falls. The Fractal D of these residents indicated that their cognitive impairment is probably at least partially, in navigation and decision making abilities.

Taxi driver journeys in the city of Shenzhen, Guangdong Province China were studied by Liu *et al.* (2009). They compared the top driver with the highest income to one with an average income, and how their journeys differed. They recorded the driver's GPS tracks and calculated the *VFractal* (part of the Fractal application suite of programs, Nams, 2010) for each of the driver's journeys (Figure 4.18).

Figure 4.18: Fractal Value at Spatial Scales 1km-10km for Ordinary and Top Driver. (Source: Liu *et al.* 2009, p. 14 web version)

They collected 1.5 million trip records using GPS and calculated how much time the top 5 drivers spent in each area of the Shenzhen locality. A Space-Time graph showed that the top drivers focus on the Nanshan District. They compared the top earning driver to a driver with average earnings and found that the top driver spends the morning and evening in Luohu-shangbu district. The average earning driver spent his morning and evening in the Central Business District where congestion is always a problem and the middle of the day in the Huangqiangbei and Shangbu area.

Taxi drivers are sometimes presumed to take the shortest route available. Liu *et al.* (2009) examined if this was true. In Figure 4.18 the Ordinary Driver had a more tortuous path than the Top Driver below 3.5 km. Above 3.5 km the top driver took the more tortuous route. Taxi drivers' earn 12.5 YUAN/km within 3 km of the city centre and beyond 3 km the fare is 2.4 YUAN/km. Within 3 km of the centre it is best to save time with straight routes; beyond 3 km it is best, in terms of earning money, to waste time on a circuitous journey.

These two papers of Kearns *et al.* (2010) and Liu *et al.* (2009) which looked at tracks of people, the first indoors, the second in taxis, suggest that a fractal analysis of firefighters' tracks taking part in a scenario exercise, should reveal behaviours that are related to aspects of navigation including they operated in the various areas of the landscape, as well as how they engaged in the tasks they were assigned.

4.5 Chapter Summary

From Alan Kay's imaginative idea for the *Dynabook* to the release of the *iPad3* and the *Samsung Note II*, took just over forty years. Ubiquitous computing was not much more than an idea in 1992 but Live/Synthetic training was happening by the 2010s.

Wireless, mobile or pervasive learning developed in parallel with other telecom services where data to was provided on location. The Webpark project

(Edwardes et al 2005, Dias 2007) allowed for images and other media to be delivered on location in wild and natural areas. The GPS tracks of park visitors recorded and participants using Webpark were found to enjoy using the application on the device. *Mscope* was trialled by the author in the development of an early prototype of CODE RED: MOBILE. *Frequency 1550* (Admiraal et al. 2009), and *Routemate* (Brown et al. 2011) are excellent examples of location based learning games. Analysis of mobile learning games and exercises like CODE RED: MOBILE can use Heatmaps, and Space Time Cube applications like *Geotime 5.3*, to determine spatial behaviours in relation to the exercise or games timeline. Fractal analysis reports on the tortuosity of a track. Tortuosity of a GPS track can be measured with Fractal D. Tortuosity can vary with the spatial scale and is a statistical fractal; and not a mathematical fractal, which is invariant at various scales. These statistical fractals that vary in tortuosity at different spatial scales show at what scales of distance animals and humans are carrying out detailed searching behaviours (high Fractal D and tortuosity) or are walking long straight paths (low Fractal D and tortuosity).

In the next chapter the development of media for learning and decision making about the bushfire in the CODE RED: MOBILE test bed, is described.

Chapter 5

Media for learning and decision making about a bushfire

5 Chapter overview

In chapter four, a short history of the development of mobile devices for learning at a location, information on location based services and games for learning and methods of analyzing GPS recorded movements of participants in training exercise and games were presented. These themes on the technology behind CODE RED: MOBILE and the analysis of learners' or gamers' tracks lead on to the development of the CODE RED: MOBILE package in chapter seven.

Pedagogy suitable for mobile learning is used in this chapter in conjunction with theories about media, cognitive artefacts, visualisations and animated movies, dynamic-static and static media to assist in the development of media for learning and decision making about bushfires. This theoretical background is then used in the design and modeling of CODE RED: MOBILE fire context in a computer game editor, and for the more detailed fire features. Finally, there is a short section describing the use of models of bushfires recorded as movies, which were used for debriefing firefighters after a real, near-miss, burn over incident.

5.1 Visualisations as Cognitive Artefacts

The intellectual achievement that separates humans from other creatures Barbara Tversky (2000) wrote, is the development of cognitive artefacts. These are devices external to the human mind that extend our cognitive abilities. They increase our efficiency of thinking by storing the knowledge required by a task to the artefact, thus reducing the working memory's

cognitive load. Diagrams, graphs, animations, movies, text, paintings, and narratives store knowledge outside the human mind. Simulations or computer games can combine a variety of these cognitive artefacts to create a virtual world that is a representation of a real world scene.

Edwin Hutchins in his book “Cognition in the Wild” (1995) described the ways that machines often contain or operate with their designer’s ideas physically embodied in the mechanism. These machines have evolved over long periods of time and are the result of many designers’ ideas or mental models of a physical or other system. Hutchins (1995, p. 98-99) gave the example of the astrolabe (Figure 5.1):

‘The astrolabe is a manipulable model of the heavens- a simulator of the effects of time and latitude on the relationship of the heavens to the horizon. The astrolabe is an early example of a general trend toward the representation of computational problems via the physical manipulation of carefully constructed artefacts.’

Figure 5.1: 18th century Persian astrolabe. Photograph © Andrew Dunn. Creative Commons Attribution-Share Alike 2.0 Generic license. (Source: Wikimedia Commons)

In a sense, when using an astrolabe, one engages in a conversation (Pask, 1976, 1992) with the heavens via the process of manipulating the astrolabe.

The astrolabe is the result of experts' mental models of how to find one's latitude using the stars. The user of the astrolabe does not have to create a mental model of the relationships between latitude and the stars' positions, but merely follows the instructions, manipulate the artefact and read off the answer. Hutchins (p. 102) wrote that these machines are:

'...physical artefacts whose structure captures regularities in the world of phenomena in such a way that computations can be performed by manipulating the physical device.'

This extends the idea of cognitive artefacts beyond depictions; they can also be 3D models, compasses, sextants, globes, street signs, 'to do' lists, maps and plans. These capture ideas, so that a person or a machine can use them as artefacts that hold those ideas outside of their own memory and yet are easily understood and incorporated into working memory. In the working memory we hold the ideas in order to work out what is happening preparatory to making decisions. There is a quest for purpose in the event depicted. In the case of observing maps and narratives about a bushfire, a firefighter is looking for what has started this fire: nature or a human hand, and what can be done to put it out or warn people about it. Cognitive artefacts in the form of an astrolabe are not looking for purpose or cause and effect, however visualisations of a bushfire usually are. Visualisation can go beyond understanding phenomena; from synthesis to vital decision making and management of a response.

Visualisation is a broad term and can be understood in MacEachren's terms (1995 p. 355) as an artefact that can induce a mental model in the mind of the beholder, to create an understanding of the phenomena illustrated :

'Visualisation is a term with many meanings. In the most general sense of "to make visible".... visualisation can also refer to making visible in the sense of mental image'. Thus the visualisation is a cognitive artefact that may be a narrative or a graph and not necessarily a depiction of a 3D scene, though it

may be. The important factor is that knowledge is stored in a cognitive artefact (Tversky 2000).

The Concise Oxford Dictionary, Fourth Edition (1950) defines ‘visualize’ (sic) as: *‘make visible to the eye, give outward and visible form to, (mental image, idea, etc); call up distinct mental picture of (thing imagined or formerly seen).’*

Visualisations have been defined by Tufte (1983) as the use of visual representations for the description, exploration, and summary of data in order to better understand patterns and relationships that they may exhibit. Whereas Battenfield and Mackaness (1991 p. 432), like Tufte (1983), provided a definition that is also concerned with finding the pattern and structure of information:

‘Visualisation is the process of representing information synoptically for the purpose of recognizing, communicating and interpreting pattern and structure. Its domain encompasses the computational, cognitive and mechanical aspects of generating, organising, manipulating and comprehending such representations.’

Andrienko and Andrienko (2006) defined visualisation as: *“making data and the corresponding phenomena perceptible to the mind or imagination of the explorer”* (p. 166). This definition is closer to that of MacEachren’s (1995 p. 355). These general definitions of visualisations embrace a search for understanding, and discovering patterns by visible means.

5.1.1 Geographical Visualisations and Geovisualisations

There are subgroups of visualisation; one is geographic visualisation or geovisualisation. Cartwright *et al.* (2004, p. 28): *‘Geographical Visualisation focuses on the application of scientific communication theory to mapping artefacts’*. This is for a scientific understanding, thus involving cause and effect and not just a means of delivering information.

In Figure 5.2 there is a geovisualisation made in a computer game with a view of Mt Macedon with Hanging Rock in the foreground to the right.

Figure 5.2: Mt Macedon contours and geology in *Unreal Tournament 2003* (epicgames.com).
(Source: screenshot by author)

The terrain is overlaid with contour lines and geology. A map with a yellow-green dot showing the location of the player is to the top left. The exercise that went with the game had a key to the geology and a puzzle to complete. The *Survivor* game was created with the *Unreal Tournament 2003* (epicgames.com) game editor *UnRealEd3* by the author and played by his students, a Year 7 class at Kyneton Secondary College (Quinn 2004). It was an experiment featuring two pairs of students each with one girl and one boy on two computers who had to race to a location in the Macedon Ranges. The location was found with verbal clues from the teacher. The students were asked to find a food tree in order to survive. It was located at 750 m on the dacite rock, coloured pink, in a south facing valley on the southern slopes of Mt Macedon. A yellow dot can be seen on the map to the top left. This showed the student who was controlling the avatar (camera) where they were. Then they ran virtually to the location they believed conformed to the clues and scored a point if they reached the target first. Students rated the *Survivor* game as satisfactorily teaching them about contours, aspect, direction, size,

scale and slope and they rated computer games highly useful for learning (ibid).

The prototype CODE RED: MOBILE features geovisualisations that display bushfires affected by a wind change. From these geovisualisations participants must find the patterns and structure of the bushfire event made *‘perceptible to the mind or imagination of the explorer’* (Andrienko and Andrienko (2006) p. 166). Firefighters can use these mental models, created by the cognitive artefact of a geovisualisations, to gain a scientific understanding of the phenomena and its causes and effects, in order to make decisions about a fire.

5.1.2 Scientific and Information visualisations

Danyel Fisher (2010) characterised the two main groups, at the annual IEEE VisWeek conference, as either scientific visualisers or information visualisers. The scientific visualisers used animation in about half the papers delivered and the information visualisers almost never used animations. The scientific visualisers were concerned with concrete dynamic processes that vary with time, and tend to relate to a real world 3D space. i.e. with vertical and horizontal axial components that correspond to a perspective view of scene.

Scientific visualization is an interdisciplinary branch of science according to Friendly (2008 p. 2): *‘...where the emphasis is on realistic renderings of volumes, surfaces, illumination sources, and so forth, perhaps with a dynamic (time) component.’*

Thus the computer game model of the Hanging Rock Reserve with a bushfire active in the landscape may be considered a scientific visualisation or scientific geovisualisation. It is concerned with constructing a mental model of a fire in the mind of the firefighter participants so that they can make decisions about what will likely happen to the fire. A screenshot of a movie capturing the scene in a 3D computer game, which is also a scientific or scientific geovisualisation, is shown in Figure 5.3.

Figure 5.3: View of Hanging Rock bushfire created in *Sandbox2* editor of *Crysis Wars* (crytek.com) as a scientific geovisualisation.

5.2 Animated movies or static images for learning?

An animation is a representation consisting of multiple images where each frame, in a sequence of frames, shows changes in time. Examples are hand drawn animated cartoons, computer animations, and movies (Bétrancourt & Tversky 2000).

Many studies have compared animations to text to discover if one is superior to the other for learning. Animated films or movies used to be hand drawn but increasingly the drawings are made using computer graphic programs. Many action movies feature special effects made with computer 3D graphics programs like 3D Studio Max (www.autodesk.com). The words movie and film are interchangeable and movie is used here. Movies made in game engines are called machinima. A machinima is made in a 3D scene created in a game engine with models of people, monsters and animals that interact in a narrative drama or adventure. In this research the movies that were created for the CODE RED: MOBILE test bed are a form of machinima and were made in *Sandbox2* (crytek.com). The machinima are referred to in this research as movies but little differentiates the final product from animations

that show tales of cartoon characters or the often simpler educational animations. Animations, movies, machinima in game engines, and computer generated special effects can all be used for learning. Training organisations and educational establishments may term them visualisations if, for example, they are data heavy or inform about a physical process. Media researchers appear to have concentrated heavily on animations rather than the other categories when looking for learning effects.

Scientific visualisations, (Fisher 2010) and geovisualisations are often in the form of an animation. A large body of research, some of which is outlined in the next section, continues to grow, examining the capabilities and drawbacks of animations for learning. Static diagrams are often found to be at least equally as efficacious as animations, especially for less complex topics. Subjects tend to learn less well with interactive animations because of the amount of time spent fast forwarding and rewinding (Fisher 2010). However she found that learners engage more with animated visualisations than static visualisations. In addition the finding that interactive animations are less useful to learning than instructor guided animations also indicates that scaffolding by an instructor assists learning. Rasch & Schnotz (2009) found that there was no significant difference between learning with text and images or visualisations that illustrated the text's concepts, but also that they did not perform worse. Thus the extra or redundant information in the form of a visualisation had no positive or negative effect.

An examination of over 100 studies of visualisation and animations for learning by Tversky, Bauer-Morrison & Bétrancourt, (2002) showed that static diagrams were better than animations in all cases. Although animations were better than text alone and better than images that specifically showed only the beginning and end of a process or event.

Contradicting these findings, Arguel & Jamet(2009) compared three treatments of media in a learning experiment: video shown alone, static pictures displayed alone, and video plus static pictures. Learning was best

with video plus static pictures. In another experiment they discovered that dynamic pictures were better than static pictures, and lessening the number of static images improved learning.

Fisher (2010) tested animated scatterplots at Microsoft Research and showed that animations were slower and more inaccurate at delivering information for learning than other multimedia modalities. Learners would forward and rewind the animations many times, whereas subjects that had a presentation by a teacher learned much more rapidly and effectively. Fisher proposed that the Tversky *et al.*'s (2002) finding that animations were not superior to static diagrams for learning was due to the learners' need to repetitively forward and reverse the animations to understand what was happening. Viewers who could explore an animation by pausing or rewinding it, learned less than others who watched an animation delivered by a presenter.

Imparting the learning of information with an animation is best done with the animation edited into sections that reflect the organisation of the information itself (Lowe, 1999). In other words the animation needs to be scaffolded and organised much like an expert's mental model of the learning. Lowe found that experts tended to want very simple data because they already have a runnable mental model and do not want the slow step of learning a new or slightly different mental model using an animation. Novices liked the animation, but on testing had missed much of the detail.

Lowe (1999) found that subjects, using animated weather map displays, focussed on the more dramatic, bigger and faster moving, rather than the most important to form their inferences. Closer things are given more relevance to inference making (Tobler 1970).

In difficult circumstances such as making firefighting decisions in the field, the predominance of saliency in inferential attentional processes, needs to be overcome by the design of graphical displays that make the important but visually weak stand out and the visually strong, but insignificant, fade into

the background (Fabrikant *et al.* 2010). CODE RED: MOBILE used elements such as annotated arrows for emphasis.

Animations advantaged learners over static visualisations because they showed the spatial relations of dynamic phenomena and thus assisted in developing mental models of the event (Russo *et al.* (2014) citing Lewalter (2002). However Russo *et al.* (2014) did not have the same findings in their study comparing animations to text for the delivery of knowledge about soil acidification, They gave participants a four minute session where half of them viewed text information and the other half animations. The participants were then given ten minutes to complete a multi- choice questionnaire. They could refer back to the media they had seen. Participants were then asked if they had remembered the information or if they had had to review the media again. In addition they were asked to rate how easy or difficult it was to do the task. They were asked also about their prior knowledge of soil acidification, whether they were colour blind and asked for general details about themselves. The findings were that there was no significant difference in performance between the groups that had received text or animations. The animation users reported that it was easier to understand the information than the text users. The eye tracking test showed that animation viewers spent a large amount of time viewing irrelevant parts the image.

A series of static pictures plus words can describe and explain dynamic features. But, Bétrancourt (2005) showed that it is difficult for such a series to show changes in time. Animations can show these temporal features. However, the cognitive load of piecing together a series of images with associated text incurs a heavy cognitive load which leaves the mind with few resources to reason about the images being observed (Sweller, van Merriënboer & Paas 1998).

Ayres and Sweller's (2005) *split-attention principle* states that dividing a learner's attention between information that is temporal or spatial lowers the effectiveness of the learning material. Mayer's (2005) *spatial and temporal*

contiguity principle presents the idea that various items of information should not be very spatially or temporarily separated. Location based support assists the integration of multiple dynamic representations (van der Meij & de Jong 2006) binding the geovisualisations to a real world location. Findings of van der Meij & de Jong (2006) were that this type of scenario presentation led to the best learning situation. In addition interactivity increases engagement with learning (Hegarty 2004) and assists in the construction of cognitive schema or mental models (Chandler 2004). The interactivity associated with the use of 7scenes in CODE RED: MOBILE together with the ability to review information at any time and to be able to rewind and fast forward the slideshows and animations was designed to assist participants learning and decision making in the CODE RED: MOBILE exercise.

Algorithm animations (Fisher, 2010) show the steps to complete a calculation or a process of sorting data. Hundhausen, Douglas and Stasko (2002) found that animations did not help students understand algorithmic processes. Their study looked at learning theories which predicted success and methodologies which were most appropriate for detecting improvements in learning using the visualisation technologies. They criticized earlier ‘integrative’ reviews as concentrating on *system expressiveness*. The experimental studies they reviewed returned mixed results overall. Constructivist learning (Kearsley 2012 citing Bruner1973, Kirschner *et al.* 2006) was a good predictor of the successful use of animations. The constructivist learning activities that worked well included an example where students made their own animations of an algorithmic operation. In another example, which worked well students were asked to answer a question using an animation; echoing the findings of Hundhausen, Douglas and Stasko (2002). Simply watching an animation was ineffective for learning.

In the CODE RED: MOBILE exercise watching an animation of a bushfire in a real world location and using it to orient the location of the virtual fire and

its predicted movements goes well beyond simply watching an animation. This is constructivist learning and was designed to help overcome some of the drawbacks of animation.

Subjects learned less with animations but they were more engaged with them, creating an emotional response (Fisher 2010). This emotional response is often what advertisers are aiming for. Damasio quoted in Milward Brown (2009): *'I never wished to set emotion against reason, but rather to see emotion as at least assisting reason...nor did I ever oppose emotion to cognition since I view emotion as delivering cognitive information.'* Advertising has looked to neuroscience to help deliver more effective messages (Milward Brown 2009). Information about objects is stored in the mind in three forms: Knowledge, Experience and Emotion (ibid p.2): *'The brain needs input from all three to form a representation of an object or concept.'* For established brands emotional advertising is more successful, and for new brands advertising that delivers information about a product is more effective (ibid). Hence for CODE RED: MOBILE, as trained firefighters are familiar with bushfire concepts and have at least some experience with them, an element of emotion and drama is designed to assist their engagement with the exercise.

Animations are not necessarily superior for learning when tested against static visualisations. However some research findings indicate that there are methods by which animations' or movies' performance can be improved by melding these forms of media to further scaffold the information. This may help exploit the emotional advantages of animations and movies as well as the informational advantages of static media.

5.3 CODE RED: MOBILE and static and dynamic-static visualisations

Pfeiffer *et al.* (2011), after a classroom experiment, found that students who identified a fish' species by studying a movie of the live fish were more accurate at its identification than a group who had used a preserved fish and

a dichotomous, keyed identification table. During a subsequent excursion to an aquarium the students were again asked to identify the same species of fish. The group who had watched the movie did this equally as well as the group who had keyed out the fish with the dichotomous table and a preserved fish.

The comparison of the separate treatments of media for learning undergone by Group 1 and Group 2 firefighter participants, delivered by the CODE RED: MOBILE test bed at Hanging Rock, were partially based on the Pfeiffer *et al.*'s (2011) ideas and protocols. This experiment, within the CODE RED: MOBILE exercise, was intended to answer the third research question:

Q.2 Are dynamic-static visualisations superior to static visualisations for learning about a bushfire, in a mobile, Live/Synthetic, training exercise?

Group 1 had general static information about the fire, such as maps and a narrative, and an annotated static visualisation of the bushfire; Group 2 had general static information the same as for Group 1, and a dynamic-static visualisation of the bushfire information.

CODE RED: MOBILE was an exercise involving recognising how a fictional or virtual fire will impact on some fictional or virtual buildings. The quality of the judgements of the participants depended on many factors including how well they formed a cognitive map of the virtual fire in the real terrain and how well they could imagine where the virtual fire moved and what area it impacted after the wind change. The information supplied by the two forms of visualisations should have merged with the cognitive map of the real terrain they acquired as they walked through the Hanging Rock Reserve. This may or may not produce better decisions and a good memory of the events. The Pfeiffer *et al.* (2011) experiment was replicated to some extent in the CODE RED: MOBILE exercise, however there is no classroom phase as such, except for the initial instruction phase where the participants are introduced into the use of the *iPad3* device and the *7scenes* application. Learning about the

fire at Hanging Rock takes place entirely in the field. In the prototype CODE RED: MOBILE exercise assistance in the field, with the device and application, was provided by a runner who responded to mobile phone calls for help.

The experiment in the CODE RED: MOBILE exercise was designed firstly to test whether the media treatment affected a participant's score on the decision making test. This was the second phase of the exercise where after viewing the three sets of information media at three locations. Group 1 had different locations to Group 2. Participants were asked to decide which of four houses would most likely burn down after a specified wind change. The *7scenes* application afforded the ability to place markers on the screen at certain locations. When the marker is selected a window opens on the *iPad 3* asking the participant to answer a question as to whether the house at this marker would most likely burn or not burn after the wind change. The *7scenes* website stored and scored the answers. This will be described in greater detail later.

A debrief test was also administered after the conclusion of the CODE RED: MOBILE exercise. This was completed on paper. It was basically a test of the participants' memory of the sequence of events. It also is a test of the cognitive map or mental model of the fire. It was, in addition, a means of ensuring at least one test measure of performance would be available, in case the *iPad 3* or the *7scenes* server did not successfully record participants' responses to the other questions. Participants' carried a *Trimble Juno SB* GPS handheld as a back up to the *iPad 3*'s inbuilt GPS. The debrief test required participants to select the correct order of events in the bushfire from a jumbled list. This was then scored by giving a mark to each item that was in correct order. If, for example, the first two items were incorrectly ordered: with event 2 incorrectly marked by the participant as event 1, and event 1 incorrectly marked by the participant as event 2; and the next 4 items marked in correct order, then the participant's score was 4/6. The debrief test was a measure of how well a cognitive map of the sequence of events had been

developed by participants; better cognitive maps should correlate with a better memory of the events in the CODE RED: MOBILE exercise. It was also hypothesised that there would be a correlation between the scores on the decision making activity, which asked participants to judge which houses would most likely burn after the wind change, and the scores on the debrief test which, it was hypothesised, would reveal participants with a better cognitive or mental map of the exercise events. It was also a simple test of memory. If the media was not efficient at delivering the information about the fire then, it was hypothesised most participants would get low scores on the debrief memory test and the houses burnt scores. If participants scored well on correctly deciding which houses burnt, but did poorly on the debrief test, then the CODE RED: MOBILE exercise did deliver the information effectively enough for the working memory but possibly not well enough for it to have been retained in the long term memory.

5.4 The advantages and disadvantages of movies or animations for learning

The dynamic-static visualisations¹⁰ (Pfeiffer *et al.* 2009, 2011) were animations of a bushfire made in *Sandbox2* and packaged for delivery in *7scenes* (7scenes.com). The account on animations in this chapter revealed a set of negative and positive attributes of animations, in particular for their use as learning artefacts. In the design of the CODE RED: MOBILE testbed the positive findings were used to design and make the animations and care was taken that as far as possible the negatives were avoided.

Negative:

- Tversky, Bauer-Morrison and Bétrancourt, (2002) found that static visualisations were better than animation in almost every case of over 100 studies

¹⁰ Dynamic-static animations have, for the prototype exercise, static annotated screen shots from the same animation spliced back in to their original location.

- Danyel Fisher (2010 p.330) related that: *‘animation can be a very powerful technique when used appropriately, but it can be very bad when used poorly.’* Fisher tested animated scatterplots at Microsoft Research (2010) and showed that animations were slower and more inaccurate at delivering information than other multimedia modalities. However CODE RED: MOBILE is not about abstract symbols and graphs, hence this finding is not directly relevant.

Images with associated text incur a heavy cognitive load which leaves the mind with few resources to reason about the images being observed (Sweller, van Merriënboer & Paas 1998). However Rasch & Schnotz (2009) found that there was no significant difference between learning with text and images that illustrated the texts concepts, but also that they did not perform worse. Thus the extra or redundant information in the form of a visualisation had no positive or negative effect. CODE RED: MOBILE did not test the differences between textual information delivery and visualisations particularly because of findings like these.

Positive:

- Bétrancourt (2005) showed that it is difficult for a series of images to show changes in time but animations can show these temporal features. The movies and derived annotated static screenshots showed the spatio- temporal sequence of the fire and it was hypothesised that the movies would enhance learning about the sequence.
- Fisher (2010) found that although subjects learned less with animations they were more engaged with them, creating an emotional response. The CODE RED: MOBILE movies and the derived screenshots were designed to have emotional impact showing how catastrophic a fire would look in a familiar terrain. A movie of a bushfire looks much more dramatic than a still image. It was hypothesised that this would, at least make the movies more engaging.

- For effective animations Fisher (2010) suggested to animate only what changes (*Necessary Motion*). In CODE RED: MOBILE only specific changes in the fires behaviour were displayed. The static images had annotations to indicate these changes.
- Animations should be edited into sections that reflect the organisation of the information itself (Lowe, 1999). Hard *et al.* (2006) recommended a hierarchical organisation of fine and coarse breaks for animations. The three sets of information both static and dynamic-static for Group 1 and Group 2 ,produced a hierarchy of scenes from the origin of the fire to its spread south, and finally showing the wind change
- Make the important, but visually weak *stand out*, and the visually strong but *insignificant*, fade into the background (Fabrikant *et al.* 2010). This was carried out being careful with the virtual camera position and orientation for making the movie and screenshots from the movie, as well as incorporating arrows and text to emphasises important features that might be missed.
- Plass *et al.* (2009) supported the notion that it is better to segment a narrative and for example view three separate visualisations, rather than show the whole at once. In CODE RED: MOBILE the visualisations of the three stages of the virtual bushfire were shown at their three real world locations.
- Ayres and Sweller's (2005) split-attention principle states that dividing a learner's attention between information that is temporal or spatial lowers the effectiveness of the learning material. Mayer (2005) recommended that spatial and temporal items be kept together. CODE RED: MOBILE kept virtual spatial and temporal information about the virtual fire at the real world locations and separated by distances that reflected the times in which the fire moved. This worked as long as participants found the information locations in the correct order.

However the order was obvious once they had seen all the information for their Group.

- van der Meij and de Jong (2006) found that geovisualisations bound to a real world location led to the best learning situation. This principle was a prime consideration in the design of CODE RED: MOBILE.
- Hundhausen, Douglas and Stasko (2002) found that animations did not help students understand algorithmic processes. They criticized earlier ‘integrative’ reviews as concentrating on *system expressiveness*, in other words how well the technology works rather than how well students learn. Overall there were mixed results for the use of animations but in general a constructivist approach to learning with animations gave better results. That is: scaffolding the learning by chunking information, and using the knowledge to examine a real problem of importance to the learner. Firefighters dealing with decision making about bushfires in the field therefore should benefit from movies in a constructive learning based exercise.
- Pfeiffer *et al.* (2009, 2011) demonstrated that dynamic-static information was superior to static information for learning. CODE RED: MOBILE sought to test if this was the case using a virtual bushfire in the real world setting.
Fisher (2010) found that learners remembered less with animations but were more engaged with them. Milward Brown 2009 wrote that people required knowledge, experience and emotion to learn about products and services. Emotion is needed to learn.

These guidelines, positive and negative were used for constructing and delivering animations and other visualisations for the CODE RED: MOBILE test bed exercise. Media construction for CODE RED: MOBILE is described in the next section.

5.5 Modelling the fire context

The Hanging Rock district was modelled in the *Sandbox2* editor that is provided with the *Crisis Wars* game (crytek.com). Three stages of the bushfire for the exercise at Hanging Rock were modelled separately using the same base terrain overlaid with vegetation, buildings and fences.

The terrain was created, using *Sandbox2*, from the Digital Elevation Model (DEM) of the area. The DEM was converted to a greyscale image, and imported to the Sandbox2 editor. The DEM is displayed in Figure 5.4. It is appears in the console to the left.

Figure 5.4: *Sandbox2* with the Terrain Editor open.

In Figure 5.4 the Terrain Editor is open and here the terrain can be altered. The terrain is in the background, viewed from above, with blue beneath. The ripples in the texture, shows as terrain when closer. Other textures are later painted onto the terrain to add realism. Areas can be raised or lowered and the surface smoothed. The height of the water can be adjusted.

Figure 5.5: Setting the WindVector values in Sandbox2.

Smoke particles and some flame types are affected by the wind vector in *Sandbox2*. In Figure 5.5 the RollupBar to the right is open, the Terrain button is selected then Environment is opened. For the Hanging Rock scene, the WindVector component, indicated by a black arrow, has been set to (0, 4, -4). The numbers equate to metres/second. The initial number X= 0 means that there is no wind influence either north or south, (north is positive, south negative number), the middle number Y=4 is a positive 4 which gives a westerly wind with a velocity of 4 km/sec or 14.4 km/hr, (negative 4 would be an easterly wind) the third digit Z=-4 is a vector that drags the smoke close to the ground. However the collision value for the particles is set so that they do not penetrate the ground. To create a plume of smoke that is rising strongly to the south the settings would be (-10, 0, 10). However the way that real wind affects smoke from a bushfire is different from the way a virtual wind affects a smoke particle in *Sandbox2*. The particles have been set with certain parameters, including turbulence of movement and an amount of randomness. However the effects of wind slowed down by vegetation and small features of the terrain does not affect the virtual smoke particles though there is substantial effect in a real fire. There is also the process by

which a fire advances that requires time to preheat the vegetation ahead of the fire to bring it to ignition temperature. This means that a real fire moves more slowly than the wind speed. However, as the movies of the bushfire only last a few minutes, the advance of the fire cannot be seen, only the location of the fire front and its direction of movement judged from the angle of the flames and the direction the smoke is going. This is aided by the maps on the mobile device showing where the fire is moving at the viewing locations.

The *Sandbox2* editor has a range of means of creating 3D entities, events and game features. The challenge for developing appropriate geovisualisations for the scenario narrative is to represent bushfire phenomena using the particle system, and cloud and fire object collection of the *Crisis Wars*, *Sandbox2* game editor to create fire and smoke effects. In the particle editor, particles of smoke or cloud can be set to respond to gravity, wind direction, air friction, friction with terrain, and changes in properties such as translation (moving in a direction), rotation and scaling. Thus a set of particles can be adjusted in the same way as a model of a car can be rotated, scaled up or down or moved in a certain direction. Colours can be added to the particles. Flames are often displayed by sequences of pictures, i.e. an animation. These animations can also be translated, scaled or rotated. The animations and particles are usually set to face the camera or point of view of the observer. Cloud models can only be scaled and translated but materials of many kinds can be added to them. From this toolbox we can create scenes that reflect the progress of the scenario narrative.

The photograph in Figure 5.6 shows a pyrocumulus that has grown above a large fire. The towering column has a brownish hue at the base. Figure 5.7 shows a representation of something similar being created in the *Crisis Wars* editor, also called the *Sandbox2* editor.

Figure 5.6: A forest fire on a ridge developing into a pyrocumulus. Used with permission.
(Source: Monica Minford, Dreamstime.com)

Figure 5.7: Adding emissive lighting to the cloud.

In Figure 5.7 the two black arrows in the lower right window point to the location in the editor where emissive lighting and emissive HDRDynamic lighting respectively can be adjusted. The sliders have been dragged to the right creating the bright highlights on the cloud. This resembles the photo of a pyrocumulus in Figure 5.6.

Figure 5.8: Ember attack, Canberra. Fires burn homes in the Canberra suburb of Duffy. Picture was taken Saturday the 18th of January 2003. Used with permission (Source: Pat Scala, Fairfax Syndication)

In Figure 5.8 smoke and embers blowing out of the fire combine with the fire glow to give a very dangerous looking aspect to the fire. Embers directly from Stringybark forest have immense potency to ignite the surface fuels as well as anything upright and flammable, whether natural or structural. In contrast burning gum tree bark tends to rise up into the air and later may descend from great heights within the pyrocumulus as it collapses after the fuel beneath it has burned, igniting distant and very large areas.

Figure 5.9: Ember Storm: particle editing. The particle count has been increased in the particle editor to the right.

In Figure 5.9 the *Sandbox2* editor is open at the particle editor section. The particle count for the embers has been greatly increased to create an ember storm resembling the Canberra fires ember attack in Figure 5.8. Gravity for the ember particles has been increased to keep the particles close to the ground and air friction has been lowered to keep the particles moving a long way over the ground from their spawning point.

5.6 Making the movies of the Crysis Wars scenes

Screen captures of *Sandbox2* scenes were made using the *Bandicam* application (Bandicam.com). This captured a selected area of the screen and the movie was saved as an .avi file.

Figure 5.10: *AVSVideoEditor*.

The *AVSVideoEditor* was then used to create the movies and to isolate the required static images from those movies. The static images were saved then imported to Microsoft Paint where arrows and text were added. The finished image was re-imported into *AVSVideoEditor* where it was spliced into the appropriate movie at the point where the still image was extracted. Figure 5.10 uses a green arrow to indicate the static image that has been placed into the movies timeline. It is followed by a standard movie indicated by the red

arrow. The orange arrow indicates where in the timeline the movie has reached: the current view of the movie which at that moment is featuring the static image. This is shown in the console to the top right.

AVS4VideoConverter was used to convert the .avi file to .mp4. This .mp4 movie was uploaded into *7scenes*, where it was made available for use in creating the mobile game elements.

5.7 Checking the realism of the fire

The 3D scene was created in the *Sandbox2* editor of the *Crysis Wars* computer game (crytek.com) and used as the set within which movies could be shot. This was a virtual backlot where props and actors (wind, smoke, fires and firetrucks) could be assembled to create a bushfire scene. It is also a cognitive artefact in that, as a 3D visualisation that has some verisimilitude with reality, it holds the 3D spatial links between objects, such that cause and effect can be observed and determined. The wind change visibly turns the smoke plume and the flames. The 3D landscape that is suddenly under threat can be seen at once and the assets threatened observed in relationship to fences and roads and landscape features.

This 3D dynamic scene is also a 3D dynamic cognitive artefact of the event. The artefact in Figure 7.4 is a mediator between the participant and the tasks in the CODE RED: MOBILE scenario based exercise. (Hutchins 1995, Norman 2007, citing Bodker 1989).

Figure 5.11 The Virtual Backlot.

Figure 5.12: Aerial photo of Hanging Rock Reserve. The photograph is used with the permission of Mr B. Hedge.

The proposed fire was seen as appropriately realistic upon presenting the initial movies on a laptop to members of the Newham Brigade who confirmed that it was suitably realistic and dramatic. Fig 5.12 is an aerial photograph of Hanging Rock and demonstrates that the model in Crysix Wars, in Figure 5.11 is similar to reality. However a Fire Behaviour Analyst (FBAN) and FBAN coach since 2011, Mr. T. Wells, operational at the CFA Headquarters,

Burwood, said that the flames in an earlier version of Figure 11 looked like an oil fire (pers. comm. 2012). Indeed oil fire flames and smoke from the *Sandbox2* editor had been used. The flames and smoke were then changed in the *Sandbox2* editor to appear more like a grass and bushland fire that later develops the beginnings of a pyrocumulus. The editing process was outlined in Chapter 6.

5.7.1 An example of a fire used for debriefing CFA firefighters involved in a near-miss incident.

Figure 5.13 was made in cooperation with Mr. R. Strickland (August, 2012), Planned Burn Coordinator and Wildfire Investigator at the CFA, Victoria. This fire was a near miss incident where a firetruck was damaged by a larger bushfire overtaking them whilst they worked on a separate smaller fire. The movie of the geovisualisation of an area near the Dandenong Ranges close to Melbourne provides views that simulate the incident. They have been used by Mr. Strickland in debriefing meetings after truck burn over incidents to illustrate how firefighters can get into difficulties in complex incidents.

In Figure 5.13 the view is a simulation of a fire close to the Dandenong Ranges, near Melbourne in Victoria, 2009. Fire trucks went to this spot fire and thought it was safe to put it out. The fire trucks were at the fire on the right. The firefighters did not realize that there were two plumes.

Figure 5.13: The plumes of the two fires close to the Dandenong Ranges, 2009.

The movie shown in Figure 5.13 was also used as part of CFA's Incident Management Training Project in a training session for sector commanders. This assisted in affirming the usefulness and practicability of using movies of animated 3D visualisations of fire features made with *Sandbox2* for debriefing and training.

5.8 Chapter Summary

This chapter looked at cognitive artefacts as embedded knowledge in objects. Visualisations are a form of cognitive artefact. Geographical visualisations, otherwise called geovisualisations, are a type of scientific visualisation. Geovisualisations are cognitive artefacts that embed in their structure a scaffolding of the knowledge they display. In the CODE RED: MOBILE exercise geovisualisations in the form of movies or screen shots of those movies of a dynamic phenomena such as a bush fire at Hanging Rock are equivalent to an animation of the bushfire. A set of principles derived from the literature were adhered to in the design of the visualisations or dynamic-static and static visualisations for CODE RED: MOBILE. A section of the chapter briefly looked at some visualisations that were used for debriefing crews in a burn over incident.

The CODE RED: MOBILE test bed delivers a prototype Live/Synthetic exercise featuring a bushfire. The exercise has a game like structure afforded by the use of *7Scenes* (7scenes.com) as the delivery platform on the *iPad 3*. In the next chapter games are considered. Initially the field of game studies is delineated followed by a history of various types of games, with a focus on games for training and learning particularly those with a geographical aspect. Concepts and ideas suitable for the development and design of CODE RED: MOBILE are summarised.

Chapter 6

Playing games seriously

6 Chapter overview

In the last chapter geovisualisations featured in the CODE RED: MOBILE exercise were introduced. These geovisualisations are a form of cognitive artefact. Dynamic-static and static visualisations for the CODE RED: MOBILE prototype Live/Synthetic exercise were delivered in the *7scenes* application for firefighter participants to learn about a bushfire, and to make decisions about where it would go and property it would affect. This training exercise, using the *7scenes* framework is in the form of game.

It was suggested by Gee (2003 p.205) that computer games for learning should work with ‘*good principles of learning, principles that are better than those of many of our skill and drill, back to basics, test them until you drop schools*’. Games, toys and sports and practising for hunting and warfare have been in mankind’s learning and entertainment repertoire for a very long time. Games from *Angry Birds* on the *iPhone* (www.angrybirds.com) to a game of chess with giant pieces in an outdoor playground are played for enjoyment and leisure. Computer and mobile games are quite compelling for many people. Hours can be devoted to *World of Warcraft* (us.battle.net/wow) or *Tetris* (www.tetris.com/). This compulsion to play outweighs time spent or the cost of buying the game and device to play it on. Games have had a long history, for example Plato in *De Republica Lib VI* (360 B.C.E), quoted in Digby (1889 p.284), wrote: ‘*...like those who play at the game of peteia without sufficient skill, who find themselves at length excluded from the line ...and had not wherewith to answer in this other kind of peteia, which consisted not in pegs, but in reasons.*’ (See Figure 6.1 for an ancient Egyptian game featuring peg holes). Since the advent of games, attempts have been made to discover what it is about some games that they become popular and last

across the ages. In the next section some of the ideas from this body of research are outlined. These ideas were used to assist in the design of the CODE RED: MOBILE exercise.

6.1 Game Theory

Games have a structure very much like a narrative. They have a beginning, a middle and an end. Like narratives of a play or novel, a game will often have a complication, this is a problem between entities that requires resolution. The player or character needs to understand what is happening, and can then begin to make decisions and determine courses of action.

The process of decision making follows a sequence according to John Boyd (1995) of: Orient, Observe, Decide then Act (OODA). John Boyd developed his OODA framework originally for fighter pilot training. Disorienting the opponent with unexpected moves was the key to winning in a dogfight according to Boyd (ibid). This was to upset the opponent's construction of their OODA. This disrupts the opponent's mental representation of the circumstances. This, in a sense, is gaming the situation.

In 2005 Mike Zyda proposed that there were three types of game (p. 25-26):

- Game: *'a physical or mental contest, played according to specific rules, with the goal of amusing or rewarding the participant.'*
- Video Game¹¹: *'a mental contest, played with a computer according to certain rules for amusement, recreation, or winning a stake.'*
- Serious Game: *'a mental contest, played with a computer in accordance with specific rules that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives.'*

CODE RED: MOBILE is a serious mobile game played with an *iPad 3*. The opponent is the bushfire and in the game participants 'Orient, Observe and

¹¹ Also termed computer game.

Decide' (Boyd 1995). 'ACT' the last part of Boyd's OODA was not facilitated in CODE RED: MOBILE.

The best games provide particular feelings, which are reported on by players as especially adding to the experience. *Presence* is one of those feelings. It has been reported by Bryce and Rutter (2001) in the context of a LAN (Local Area Network) Party, where participants brought their own computer and engaged in a joint game of *Quake3*. The feeling that the player was truly present in the game was enhanced by their physical participation at the party, together with the virtual appearance within the game of their customised avatar. Many games allow you to choose your name and the skin (or covering) of one's avatar.

In addition, during a game, the sensation of *flow* was felt, Bryce and Rutter (2001) citing Csikszentmihalyi (1975). This is an intense involvement of the player, where he lacks self-consciousness, with the feeling of being in control, and possessing the capacity to accomplish the task or mission.

In a similar manner interactive texts can provide feelings of pleasure. Janet Murray (1997) described three key pleasures that differentiated a traditional text from an interactive one. The interactive text has *Agency*: the power to act on objects. *Immersion*: a feeling that you are truly there. *Rapture*: a belief that the characters, settings and other entities exist and there is the development of an emotional *Attachment* to them. These terms are also used to describe feelings associated with playing computer games.

Interactivity has been defined by Mortensen (2002 sect. Between Reading and Experience) as '*in connection with a computer game, it reflects an outer rather than an inner process... it demonstrates the extent to which a program will react to acts performed by the user- a form of reactivity, rather than interactivity.*' This is more a criticism of simulations or games that are described as interactive, but in fact only have basic navigation through a text

or simple scene. Mortensen in analysing a Multi User Dungeon (MUD), a text-based role-playing game, described a higher level of interactivity with the game than mere navigation (ibid). Participants in the MUD could undertake roles in the game beyond being mere players and create new characters. A player might manipulate the plot through her choices and a player could become a co-author of the MUD (ibid).

Interactivity, in games, was analysed by Ryan (2001) and divided it into two dyads: *exploratory*, (the freedom to move about in a game), and *ontological*, (being able, through a process, to choose what changes). The second dyad's end points are firstly *internal*, which is the ability to either see the world through the eyes of the avatar and secondly *external*, or viewing the world from above, as with a god-like view (Ryan 2001). *Internal* is another word for egocentric and *external* another word for allocentric view.

Using the two dyad's interactivity dimension Ryan (2001), provided a genre based taxonomy for interactivity: hypertext novels are *external/exploratory*; mystery, soap opera and parallel plot, interpersonal relations, spatial narrative and narrative of place are *internal/exploratory*. Branching videos choose your own adventure stories and computer games like *SimCity*, *SimLife* are *external/ontological*. Action and adventure games such as *Crysis Wars* and *Unreal Tournament 2004* are *internal/ontological*.

Ryan (2001) posed the idea that *internal* and *external* views of the narrative world are a dimension of interactivity with the world. She uses the *internal* and *external* terms not as being related to navigation or the understanding of context but specifically the view from inside the eyes (or egocentric) or the scene imagined from above (allocentric).

In her book *Hamlet on the Holodeck* (1997), Janet Murray proposed an aethereal virtual world where players could engage with fictional characters and take part with them in narratives generated by a machine. She put forward that (ibid p. 142-143): '*a game is a kind of abstract storytelling*' and '*games can also be read as texts that offer interpretations of experience*'.

Narrativity is the extent to which there is a narrative structure in a game. In the *Poetics* (330 BCE), Aristotle wrote that a story or a play's plot, has a beginning a middle and an end, which respectively: sets the scene; develops the complication, and provides the possibility of a resolution. Marie- Laurie Ryan (2001) divided narrative into two forms: diegetic narration or storytelling and mimetic narration where actors perform the roles. Both forms of narrative have characters in a plot with events at a place and time undergoing a change.

Diegetic narration is the acting out of the players in any form of drama, non-diegetic narratives are for example cut scenes or videos introduced at major breaks in a computer game that further the plot. Non- diegetic presentations are external to the acted out story. Diegetic music in a movie is for example when a radio is playing in the scene and is heard by the characters. Non-diegetic is the background music that we know is not heard by the players. It sets the mood for the audience alone.

6.1.1 Viewpoint

Whether a narrative is diegetic or not is a matter of the viewpoint and whether one is embedded in the game context as a player or outside of it as an observer. In many games, with an allocentric view from above, one is at once a participant and an observer, one can hear opponent and in-game diegetic sounds, as well as non-diegetic music that sets the mood for the player, but not the character in the game.

For the purposes of this research, the 3D view that a player has of a scene is termed *egocentric perspective*. This is where the camera is looking forward out of the avatar's eyes. If the view on the screen is from a camera that is above and behind the avatar you are controlling then it is termed here an *allocentric perspective* view. If the view is god- like, from above, it is an *allocentric* view. The *allocentric perspective* view does not show the whole context of the game but it does show other players to the side and is a more *allocentric* view than the narrow egocentric view. In some games the viewer's camera is untethered

and can fly anywhere, providing an *untethered perspective* view, fly high enough and look down with the camera and the view becomes an *allocentric* view.

In many computer games a small map shows the player and other avatar's locations. If the map view remains north oriented and still whilst the player's icon moves, then it is an *allocentric plan view* (Quinn and Cartwright 2008). In *egocentric plan view* the map rotates its orientation to the player's orientation; the player's icon stays at the centre of the map while the map scrolls with the player's movements. In the *allocentric plan* view the map stays still while the player icons move about and all other player's locations can be usually seen. For the *egocentric plan* view the player stays at the centre of the map whilst the map rotates as the player's icon changes direction. Views in visualisations made in computer game editors can also show these views, an allocentric view from above gives the overall context, a tethered perspective view following a vehicle might show the nearby context, perhaps a threat from a bushfire.

These suggested terms match similar ones from cognitive science with egocentric navigation being about establishing a context for oneself whilst exploring a new environment or an environment that is undergoing alteration, perhaps from the movements of a bushfire. Allocentric cognitive maps are a god like view of the context of the whole game space.

It is quite difficult to use an *egocentric plan* view in a simulated battle or bushfire, one resorts if one can to the *egocentric perspective* or, and preferably, the *allocentric perspective view*. In real life one does not have that luxury and one has to cope with a narrow *egocentric* view with repeated turning of one's head and body to gain the all around view. People however do have the luxury of maps, visualisations and conversations to convert multiple egocentric views on the ground into an allocentric understanding.

6.2 Rules in games

In *Rules of Play: Game Design Fundamentals* Salen and Zimmerman defined a game (2003 p.80) as: ‘*a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome.*’ This idea of a game as purely about conflict is a narrow one as sometimes games are about exploration or learning and sometimes about play or entertainment.

Citing and criticising Roger Caillois’s (1979) labeling of two aspects of gaming as *ludus* and *paidia* Koster wrote (2005): ‘*paidia activities generally have MORE rules, not less; ... whereas ludus games are ones that have been tightly defined.*’

Ludus duodecim scriptorium was the Roman board or table ‘*Game of the Twelve Lines*’ (Walker 2012). In the Roman game there were three rows with twelve spaces each. Players threw 3 dice and raced each other around a board. *Ludus* means a game with rules. *Paidia* on the other hand means free play without rules. Caillois proposed a dyad with *paidia* one end and *ludus* the other with increasing structure and rules towards the *ludus* end. *Ludus* tends to be an engagement with some form of reality; *paidia* with the fantastical. Eva Nieuwdorp (2009) asked what happens where *paidia* and *ludus* intermingle. She conceived of them not as irreconcilable opposites but as capable of interfacing. Nieuwdorp described pervasive games as a new game genre. Pervasive games can combine *ludus* with *paidia*.

In the next section a history of games is presented.

6.3 Games, with location as a principal focus

Figure 6.1: Wooden gaming board for ‘Hounds and Jackals’. Played probably with a pair of knuckle-bones. Egypt : Dynasty 9 c. 2160-2130 BCE. UC31348. (Source: The Petrie Gallery, University College London. Image with permission)

Table top games were played in ancient Egypt at least as early as the Ninth Dynasty. The table for Hounds and Jackals is shown in Figure 6.1. The peg holes can be seen in the top of the wooden table, where players would push in pegs representing the animal hunt. Knuckle bones would have been used like dice.

Christopher Weikmann in 1644 created what was called the King’s Game or KönigSpiel. It had 30 pieces for each side representing 15 types of military personnel. In 1780 this was taken further by Helwig, Master of Pages to the Duke of Brunswick. The board had 1660 squares, each with a type of terrain that affected the movement rate through the square. There were special rules for various units e.g. the pontooneers. Georg Vinturinus from Schleswig in Germany 1795 adapted Helwig’s design, and in 1798 used a mapboard based on the terrain between France and Belgium (Gray 1995).

Baron von Reisswitz who counselled the Prussian court, created in 1811 a game that used a sand table rather than a gridded map. It was at the scale of 1:2373. It was played at the Prussian and Russian courts. In 1824 the Baron's son produced a new version based on topographical maps and with improved rules of combat. With the patronage of the Prussian Prince Wilhelm and the enthusiastic approval of the Chief of the Prussian General Staff, General von Muffling, the game was provided to all Prussian regiments. After the 1870-1871 Franco –Prussian War, when France was defeated, many military services took up the concept of wargaming. Wargames were widely used in all subsequent wars (ibid).

Wargaming as a hobby began in 1913 subsequent to the publication of H.G Wells' *Little Wars: A Game for Boys from Twelve Years to One Hundred and Fifty and for that More Intelligent Sort of Girl Who Likes Games and Books*. In the game toy cannon fired shells at toy soldiers. Thus began the hobby of using miniature model soldiers, in rule based battles, on modeled landscapes (ibid). Charles Roberts in 1953 designed a game called *Tactics*, which used paper pieces on a cardboard map (ibid). He founded the Avalon Hill Company that produced many other games. The board adapted the hexagonal instead of square grid, as the basis of movement, from an idea of the Rand Corporation (ibid). This equalised the length of moves. In square based boards a piece, moving the same number of squares, can move further on the diagonal than the orthogonal. This does not realistically represent the energy expended by soldiers actually traversing a terrain. *Gettysburg*, *D-Day* and *Stalingrad* were published by Avalon Hill.

6.3.1 Computerised games

In 1948 "*Air Defense Simulation*" was developed by the Army Operations Research Office, at Maryland's Johns Hopkins University. It was the first computerized war game. In 1953 the "*Carmonette*" series of games was devised. These games automatically calculated the results of moves and other features of the war or battle (ibid).

The U.S. army partially funded the development of the Firefight (1976) board game by Jim Dunnigan and Irad B. Hardy. It was a tactical game of mechanised combat of the late 1970s between the Nato and Warsaw Pact forces. The game was designed for the U.S. Army Infantry School by J. Dunnigan and Lt. Col. Ray Macedonia of the U.S. Army and later released as a board game by Simulations Publications (Inc) (Lenoir & Lowood 2003). Between the 1960s and 1970s wargaming had ceased to be utilized by the US Army (ibid).

A wargame was defined by the U.S. Department of Defense Joint Chiefs of Staff (1987) cited by Lenoir and Lowood (2003 p.2) as: '*a simulation, by whatever means, of a military operation involving two or more opposing forces, using rules, data, and procedures designed to depict an actual or assumed real life situation*'.

In 1977 Andrew W. Marshall, director of Net Assessment for the Department of Defense asked James F. Dunnigan (ibid) to create a global strategy game and this became the *Strategic Analysis Simulation*. The *McClintic Theater Model* (MTM) at the Army War College was developed in the 1970s featuring multiplayer, networked games (ibid). In the mid 1990s-1980s MTM became *Joint Theater Level Simulation* (JTLS) (ibid).

In the meantime at the University of Illinois at Urbana the *PLATO* project developed multiplayer wargames starting in the late 1960s (Dunnigan 1997). One of their programmers Chris Crawford published TANKTICS for the Commodore PET PC in 1978. The game was played by entering text. There were no graphics. The player kept track of 8 tanks, 4 German and 4 Russian using a map, with several terrain types and cardboard pieces.

In 1980 the PC was introduced and wargaming in the home became computerized. The computer took away the drudgery of calculating damage and the many possibilities of cheating with small pieces of cardboard easily moved and lost. Game state could be saved whereas cardboard pieces easily go astray. It allowed a game to be played over weeks and it introduced the

automatic opponent, the artificially intelligent player inside the game's software. Solitary gaming became more interesting. Since the 1980s the capabilities of computer graphics have vastly improved and, as can be seen in this work, *Crysis Wars* (crytek.com) displays impressive terrain and bushfires with reasonably realistic smoke and fire.

Roger Smith, chief scientist and technology officer for the USA Army's Program Executive Office for Simulation, Training and Instrumentation is quoted in an article by McLeroy (2008 sect. Computers Arrive):

'Military-training simulations like JANUS and SIMNET have been incorporated into simpler commercial games. "America's Army," a modification of Unreal Tournament;" DARWARS Ambush," and adaptation of "Operation Flashpoint;" and X-Box's "Full Spectrum Warrior" have all been used by the military'.

SIMNET had shortcomings and these were amended with the Institute of Electrical and Electronics Engineers (IEEE) Distributed Interactive Simulation (DIS) network software architecture standard (Hodgson 2009 pp. 8-9). Distributed Virtual Simulations (DVS) were developed from SIMNET by the US Army Defense Advanced Research Projects Agency (DARPA). DVS are for training operators using the system and for making interactions with the virtual world more realistic.

6.4 The Mobile World

The Digi-Capital global video games investment review (Digi-Capital 2011) for February 2011 reported that *XBox360* and *Playstation 3* games cost between US\$15-30m to develop and Wii games US\$5-7M. Globally in 2009 Video Games earned US 77 billion and Film US\$85 billion.

Mobile phones were possessed by 67% of world's population in 2009 (ibid) according to the review. In 2009 online and mobile games were 32% of the global video games market earning US\$19 billion and in 2014 predicted to be 50% of video game market earning US\$44 billion (ibid p.11). Mobile games

are much cheaper to produce with development costs “tens to hundreds of thousands and not millions” of US\$. Over “10 billion iPhone apps have been downloaded” many of them games (ibid).

Commercial desktop computer games are relatively expensive to develop. Mobile game development though, tends to be relatively modest in cost. The cost is worth the investment because computer, console and mobile games are large worldwide businesses that can make considerable profits for their investors. The ubiquity of games in many homes around the world has led to a familiarity with them that has contributed to their acceptance as valid forms of media for entertainment as well as for serious purposes.

In the next section Pervasive games, are addressed. These are often outdoor games that use real buildings and terrain as a setting. The game itself may or may not use parts of the location and the setting as features in the game.

6.4.1 Pervasive Games

The context of a pervasive game can be anywhere, with players’ performances resembling a performed narrative on a stage. There is a complication to be overcome but with the real world as the performative setting. This adds a juicy frisson to the performance.

Immersive games are a sub- genre of pervasive play (McGonigal 2003).

Pervasive play or mixed reality games use mobile technologies to create virtual places in ordinary spaces. Immersive games hide the notion that it is play or a game and disbelief is suspended (ibid). The ‘suspension of disbelief’ is an idea of Samuel Taylor Coleridge presented in his 1817 book *Biographia Literia*. However, for immersive gaming the players signal to each other that they believe it is reality. Kendall Walton in *Mimesis as Make-Believe: On the Foundation of Representational Arts* (1991), argued that scenery and props such as furniture and weapons, aid in transforming the actor’s internal suspension of disbelief to a shared external performance of belief with the other actors and the audience. Indeed, in scenario-based training exercises,

firefighters act as though the virtual fire is real, and the firefighters act as though the forest and houses really do burn.

Gentès *et al.* (2009) list four elements that structure a pervasive game: the physical organisation of the city; the narratives of the imaginary city; the services of the functional city; and city events. Events can be arrivals of trains. The timed rhythm of the city has a corollary in rural and wild areas, where there are spatial and temporal events such as harvest time, or rainy and dry seasons.

Pervasive game pioneer Steve Benford, as described by Girardin (2005), categorised the various forms of pervasive games:

- Mapping classic computer games onto real-world setting (e.g. Human Pacman (Reymond 2010))
- Focus on social interaction e.g. CatchBob! (Girardin 2005)
- Touring artistic games e.g. Uncle Roy All Around You, Can You See Me Now? (Benford *et al.* 2006), Wi-Fi.Bedouin (Bleecker 2004)
- Educational games e.g. Savannah, (Facer *et al.* 2004)

Montola defined a pervasive game (2005 p.3) as: '*a game that has one or more salient features that expand the contractual magic circle of play socially, spatially or temporally*'. Montola (2005) described them as games that are not bounded by Huizenga's Magic Circle (1955). They elude the metaphorical Magic Circle's temporal, social and spatial powers to contain play. The notion of play: that this is not ordinary life is also broken. He contended that pervasive games include a diverse range of sub- genres. *The AI game* otherwise *the Beast* is a collaborative problem solving game (McGonigal 2003), *Botfighters* is a location based mobile game, *Visby Under* is Augmented Reality (AR) with game features and *Can You See Me Now* is a game with real and virtual elements (Benford *et al.* 2006). (op cit).

The allocentrically minded player is aware of the game in its location, player or character context and also the real participants' context. The location can be partly fictionalized or a real historical place, such as the Tower of London. The player is a character but can also make friends with other characters' real personae. The game may not require any, or little in the way of IT or electronic devices.

Ubiquitous information technology were described by Alvarez and Michaud (2008 p.64) as an: '*environment that combines both the real world and an IT dimension. The latter may well be hidden from the eyes of the users*'. The extension of this is the ubiquitous game, where a game integrates the reality of a place with information technology.

Pervasive Games like *Killer: The Game of Assassination* (Jackson, 1998) requires only rules, a group of people and water pistols, with no IT or electronic mobile devices (Montola 2005). In contradistinction Magerkurth *et al.* (2005) described pervasive gaming as real world games augmented by computing devices. There is disagreement, but the debate at present seems to have swung in favour of pervasive games being agnostic as to technology.

The Beast used natural settings mostly in Manhattan, New York (McGonigal 2003). Immersion is a (ibid p. 4) '*virtual engagement with reality*'. Virtual play was part of the daily lives of players as they sought clues in the media, in the film 'AI', and in public meetings. They were mailed packages of information. *The Beast* was a project of Microsoft and Dreamworks to publicise Steven Spielberg's 2001 film *Artificial Intelligence* or *A.I.* *The Beast* was devised and directed by Sean Stewart. It is estimated that over one million people played the game mostly in large groups on- line (ibid).

The *Nokia Game*, in contrast was a mobile multiplayer location based game. Nokia emphasised that it was a game for entertainment. A Website gave rules and details of prizes. In November 2002 it was being played by over one million people in 25 countries. McGonigal (2003) claimed that immersion in

the *Nokia Game* was hampered by the use of mini Flash games played on the mobile device. These required the player to control an avatar whilst clicking on objects to gain information and objects for the game. This makes it look and feel to the player like a pervasive game operating outside reality rather than an immersive game based in reality (McGonigal 2003 p. 5).

6.4.2 Location based games

Location based games are computer games where the player's location has a bearing on the game play (Benford *et al.* 2004). Capra *et al.* (2005) summarised in Raper *et al.* (2007), defined location based games as mobile public interactions at specific locations that integrate elements of the physical world with digital devices and programs. They divided location based games into those derived from outdoor activities like hunting or hide and seek and those from board games. Location based games require good positioning technology or at least an adequate means of taking account of the sometimes uncertain position determined by the device. The real world setting needed to be well considered at the design stage along with associated virtual digital media and the game would need a convincing narrative to overcome real world inadequacies (Raper *et al.* 2007). *Geocaching* is an example of a location based game where players provided with GPS coordinates find sequestered items or clues to a puzzle.

6.4.3 Examples of some location based games (Raper *et al.* 2007)

PacManhattan (<http://pacmanhattan.com/about.php>) is based on the 1980's *Pac-Man* game where a creature gobbles up monsters around a maze. In the streets of New York players collect virtual dots whilst others try to catch them before they have all the dots. The players are tracked and can use mobile phones to contact each other.

Tourality (<http://www.tourality.com/>) challenges the player to beat opponents to positions displayed on a mobile phone map. A GPS based application on the mobile phones showed all players positions.

Uncle Roy All Around You (Benford *et al.* 2006), was a game actively being played in June, 2003 where some players were in the real world with handheld computers while others played virtually in a PC game scene that showed the same area of the city. Online players helped street players get to sought locations by exchanging private messages. The street player arrived at an office where the online player could see them on a Webcam and chat. Out in the street the player met a stranger who invited them into a limousine where they were enjoined to assist a stranger for a year. The limo took them back to the Institute of Contemporary Arts, London, where the player had originally registered for the game. This cycle had to take place in one hour. The online player then waited for more street players to participate.

Mogi Mogi (Hall 2004) was a mobile game based in Japan. Virtual objects could be seen on a moving map, and acquired as the player got nearby. These objects could then be swapped with other players to complete their collection. It was developed by Mathieu Castelli at his company Newtgames.

Mobile Chase was produced by Fetter *et al.* (2007) using their *Mobile Framework*. The location based game framework was programmed in *Java* and supported *J2ME*, *J2SE* or *J2EE* which are common versions of *Java* available on many mobile devices. The framework is technology based rather than a game framework. The program had four basic entities: *User*; *Marker*; *Job* and *Message*. *User* and *Marker* inherited *PositionableObject* which gave the position of the entities, as well as names, team name and associated images. *User* showed the players' identity and position and *Marker* was a location at which some action is triggered or the player could acquire some object. A *Job* was some task a *User* or *Marker* should achieve. *Message* provided the capacity for *User* and *Marker* entities to communicate information. The *GameWorld* was an abstract *Class* on the Server and Client devices resulting in a *ServerGameWorld* and a *ClientGameWorld* that connected the four basic entities with game rules and a game world. These also dealt with the rendering of the visible game entities to the respective screens.

In a game of chase; the people who laid the trail took geo- referenced pictures of their location as they ran to a goal. These were sent to the server which made them available to the chasers' mobile devices. The GPS locations were used to place the photographs in a 3D view showing the photos true distance and direction from the previous photograph in a succession of placed and oriented photographs that went back to the start location. The chasers had to infer down which street the prey had gone and had to chase and capture them before the time limit expired. They were captured when the pursuers' mobile phone was in range of the Bluetooth reception of the trail layers' mobile phone. This was a novel concept for a simple game that used an application framework lending itself to further research on location based mobile games.

Matyas (2007) showed that GPS tracks of players in a location based mobile game called *CityExplorer* recorded over 74 hours created a map of the city of Bamberg in Germany.

'*Team Exploration*' a pervasive treasure hunting game (Figure 6.2) was produced by Gentès *et al.* (2009). They argued that the layout of the city, the city's stories, histories, city's services and city events needed to be considered in the design of a pervasive game. In addition urban anthropology needed to be researched. The engagement with real geography, history and commerce rather than virtual, required a new look at what Gentès *et al.* (2009) called the anthropological aspect. In addition they claimed that the *ad hoc* mediation of the mobile game transforms relations with space, place and neighbourhood. There is no central server in the game so the players are forced into sharing experiences to gain an overall view of the game, through dialogue.

Figure 6.2: ‘Team Exploration’ (Source: Gentès and Jutant 2012)

Gentès *et al.* (2009, p. 7): ‘In ‘Team Exploration’, relation to space was therefore not a question of pointing out things and people on a map like in “CatchBob!” but of organizing a spontaneous social network based on co-presence in a physical space’

Gentès *et al.* (2009) found that players preferred neutral settings like railway stations for their ‘play’. Suburbs and religious buildings and work places like offices and factories were non neutral in feeling and a vantage point from which players could observe the non neutral areas (ibid p.9): ‘They are windows onto the outer world’. This is curious and reveals something about the relationship of the players to territory.

6.4.4 The essential elements of location based games

These are games afforded by the computer in which location has a bearing on the game play (Benford *et al.* 2004). However they can include games like *geocaching* that focus on locating items that can be swapped for a personal item, recording in a buried log book when you found the cache. *Mogi Mogi* (Hall 2004) is similar to *geocaching* in that tokens are collected when in proximity to the player’s mobile device. The tokens can be swapped with other players to complete the collection of tokens.

Location based games often involve other people like in *Uncle Roy All Around You* (Benford *et al.* 2006), in which online players assist street players to find their next location. *Mobile Chase* (Fetter *et al.* 2007) had players laying a trail of georeferenced photographs that the chasers had to follow and once in Bluetooth range the chasers were taken to have captured the trail layers. In *Team Exploration* (Gentès *et al.* 2009) a locally networked game required players to find items like street art on walls. Players found this game thrilling, showing ‘*flow*’ and ‘*immersion*’ (ibid). Excitement and fun is an essential aspect of these games (Figure 5.9). Navigation through rural, wild or urban areas is required but made relatively easy with GPS devices. Map reading skills are important to some extent but little knowledge of a local area or its cultural or ecological aspects is required to complete these types of games. These games are for entertainment but through navigation in the game the player learns something about the location itself.

6.5 Games for learning about location

Pervasive location based games are generally for entertainment and relaxation compared to games but have been adapted for learning purposes. At the beginning of this chapter ancient games and later wargames were introduced. Here, a survey of the development of pre- computer games for learning is considered.

6.5.1 Early games for learning about location

John Locke (1632–1704). *Some Thoughts Concerning Education*. 1693. (Locke 1693 sect 149-150):

‘§ 149. *Thus children may be cozen’d into a knowledge of the letters; be taught to read, without perceiving it to be any thing but a sport, and play themselves into that which others are whipp’d for...* § 150. *I have therefore thought, that if play-things were fitted to this purpose, as they are usually to none, contrivances might be made to teach children to read, whilst they thought they were only playing.*’

Figure 6.3: *The Goose Game*, c. 1650 attributed to Valerio Spada (1613-1688). Etching and engraving. Image is with the permission of Waddeston Manor, National Trust. Image © Waddesdon Manor, The Rothschild Collection (Rothschild Family Trust). Photo: Mike Fear.

John Locke may have been familiar with board and gambling games. The *Game of the Goose* (Figure 6.3) dates back to the mid 16th Century. It was a gambling game using two dice. Landing on a goose square gave the bonus of going forward the same distance as just thrown. In some versions of the game if you landed on a skull square you then went back to the beginning (Alvarino XM n.d.). This would not have been regarded as suitable for children as it was for gambling and threatened the road to ruin rather than enlightenment.

John Locke would have been perfectly pleased with Pierre Duval's 1645 game *La Jeu de Monde* displayed in Figure 6.4. It is an educational variation of the *Game of the Goose* and believed to be one of the oldest games featuring maps. Players rolled dice and went from the polar regions through New Canada on the outside reaching France at the centre. Australia does not feature.

Figure 6.4: Le Jeu du Monde, Pierre Duval, 1645. Image used with David Rumsey's permission. (Source: <http://www.davidrumsey.com/luna/servlet/s/yff293>)

Figure 6.5: *The Royal Geographical Pastime or the Tour of Europe* by Thomas Jefferys, London 1768. Photograph of game by Adrian Seville and in his collection. Image is with A. Seville's permission. (Seville 2011)

The Royal Geographical Pastime or the Tour of Europe by Thomas Jefferys, illustrated in Figure 6.4, was a later edition of the original 1759 cartographic game published by Carrington Bowles based on the gambling game: *Game of the Goose*. In Jefferys' game players toured Europe using the same rules as the *Game of the Goose* (Bayfield 1997).

Figure 6.6: Wallis's *Tour of England and Wales, A New Geographical Pastime*, published 1794 by John Wallis. Image used with permission. (Source:

http://www.oldworldauctions.com/archives/detail/lot_images/119-481A.jpg, viewed 23 June 2013)

John Wallis in 1794 published '*Tour of England and Wales, A New Geographical Pastime*' (Figure 6.6). It was played with an eight sided teetotum, a spinning top with numbers on the side, three pyramids for travellers and four markers for servants. The tour round England and Wales visited 117 towns and cities. At some places the traveller had to stay for more than one day (Bayfield 1997).

Australia features (Figure 6.7) in John Wallis' *Complete Voyage Round the World, A New Geographical Pastime*, published in 1796.

National Library of Australia

nla.map-rm36-

Figure 6.7: Wallis' *Complete Voyage Round the World, A New Geographical Pastime*, published in 1796 by John Wallis. Copyright expired. (Source: <http://www.slv.vic.gov.au/latrobejournal/issue/latrobe-60/latrobe-60-086.html>, viewed 23 June 2013)

Captain Cook is mentioned in 8 places. Players visited 'Owhyee' and stayed one turn (Bayfield 1997 p. 151): *'to see the bay where Captain Cook was unfortunately killed in a contest with the natives'*. The travelers also visited Botany Bay where they stayed for two turns. This is space 52 that traditionally in the *Game of the Goose* is the *Prison* (Seville 2010). On the map Tasmania is still not recognised as a separate island.

Figure 6.8a: An Amusing and Instructive Game. Walker's Geographical Pastime or Tour through the Western Hemisphere or New World. An Amusing and Instructive Game. William Darton 1816, London. Permission granted to use image. (Source: http://www.raremaps.com/gallery/detail/32235/Walkers_Geographical_Pastime_Exhibiting_a_Complete_Voyage_Round_the_World/Darton.html)

Figure 6.8a display Walkers game map drawn by William Darton. The game was provided with two booklets. Port Jackson and Botany Bay are marked a long way apart. Sydney has not yet become the standard name for the penal colony. Tasmania is shown as separate from Australia in Figure 6.8b.

Figure 6.8b. Australia and Tasmania detail from Figure 6.8a.

Figure 6.9: *The Travellers or a Tour through Europe*, published by William Spooner 1842. Permission to use image granted by Bonhams Auctioneers, London. (Source: <http://www.bonhams.com/auctions/13640/lot/94>)

In 1842 William Spooner (spoonerism is named after him) designed and published *The Travellers or a Tour through Europe* (Figure 24). Players rolled a 4 sided teetotum like a spinning top. The 4 sides were marked east, west, south and north. They moved from one latitude and longitude lines intersect to another going in the direction mandated by the teetotum. If they started from Jerusalem they had to get to Vienna, if from Cairo to St Petersburg. Upon reaching a city they had to say what country it is in otherwise they forfeited some counters. If they lost all 20 of their counters they were out of the game. The first player to get to their specified city took all the counters. Although the classical cities still feature, the native fauna of Europe are also featured. Wilderness and wild animals are seen as attractive to tourists.

Figure 6.10: *The Race to the Gold Diggings of Australia* c. 1855

(<http://www.slv.vic.gov.au/latrobejournal/issue/latrobe-60/latrobe-60-089.html>)

The Race to the Gold Diggings of Australia ca 1855 (Figure 6.10) is described by Bayfield (1997 p.154): '*as without any virtue at all*'. It had 6 lead ships and a rule book.

Figure 6.11: *Around the Commonwealth by Aeroplane*, ca 1910, published by National Game Company, Melbourne. (Source: <http://catalogue.nla.gov.au/Record/1190782>, viewed 23 June 2013)

Around the Commonwealth by Aeroplane published in about 1910 (Figure 6.11) marked the site of Canberra the future capital. The flight was by biplane.

Figure 6.12: *Bound for Berlin*. Published by D.J. Wildey, Sydney NSW, 1917? (Source: <http://www.samemory.sa.gov.au/site/page.cfm?c=5565&mode=singleImage>, viewed 23 June 2013)

Bound for Berlin is presented in Figure 6.12 and was produced late in the First World War in Australia (1917?) reflecting the patriotic fervor of wartime.

For much of the 20th Century games would be regarded as purely for entertainment and not educational. Formal schooling for all, following the Education Acts of the 1870s, has been blamed for the decline of games for learning (Government of South Australia, 2010) and the resulting dearth (for some) of '*Delectando Monemus*'. Until the late 1960s games for learning were out of favour.

6.5.2 Simulation games

Philip Gillispie defined *simulation games* (1973 p.3) as:

'Attempts to devise an environment for participants...that they would not normally experience- an environment that abstracts from reality those social, economic or political phenomena that, together, make up a

complex and confusing situation, but when reduced by simulation, become comprehensible, revealing and educational in the broadest sense’.

Simulation Games were popular until the advent of desktop computers. *Clug* published by Urbex Affiliates was a significant example. Gillespie (1973 p. 19) quotes its purpose, written by Professor Allen Feldt of Cornell University:

‘The Community Land Use Game (CLUG) attempts to reduce the broad range of variables supposedly affecting urban land-use decisions to a small number of basic attributes of cities...by making decisions about how these basic components are to be employed, players build, operate and maintain their own community’.

CLUG was played on a gridded board and decisions were made by players who performed roles in teams of developers. They used their initial capital to increase the value of their investments as well as add value to the community (Anderson and Shove, 2001).

Gillispie wrote (op cit) that it was as exciting as *Monopoly* (http://www.hasbro.com/monopoly/en_AU/). The board game was later computerised and sold by a company called Complex. Part of the board is displayed in Figure 6.13 and illustrates the wooden pieces representing buildings.

Figure 6.13: *Community Land Use Game (CLUG)*. (Source: Anderson and Shove, 2001, p.61)

Marc Prensky in his article *Digital Natives, Digital Immigrants* (2001) wrote that the average college graduate in the U.S. had spent 5000 hours reading, 10,000 hours playing computer games and 20,000 hours viewing television.

Learning Game	Date	Description
<i>LOGO</i>	1967	A programming language which students can use to control the movements of a turtle to draw shapes. Popular in mid 1980s. Designed at Bolt, Beranek and Newman (BBN) 1967 by Wally Feurzeig and Seymour Papert. (http://www.princeton.edu/~achaney/tmve/wiki100k/docs/Logo_%28programming_language%29.html)
<i>Lemonade Stand</i>	1979	Apple II game. Students buy, advertise and sell home- made lemonade to make a profit. Published by Minnesota Educational Computing Consortium (MECC). (http://edugamesresearch.com/blog/2008/09/16/the-top-10-most-influential-educational-video-games-from-the-1980s/)
<i>Oregon Trail</i>	1985	Apple II game. Settlers battle hardships to traverse the Oregon Trail in 19 th Century U.S. Designed by Don Rawitsch, Bill Heinemann, and Paul Dillenberger in 1971. Published by MECC in 1974. Popular commercial version released in 1985. (http://www.evi.com/q/facts_about_the_oregon_trail_5)
<i>Where in the World is Carmen Sandiego?</i>	1985	Apple II Broderbund game. The player chases Carmen, a thief, answering geographic questions to foil her plans. (http://www.carmensandiego.com/hmh/site/carmen/home/articles?article=44106&categoryname=fanfare)
<i>Math Blaster</i>	1987	PC and Macintosh. Published by Knowledge Adventure. Mathematical puzzles made fun. (http://www.mathblaster.com/About.aspx)
<i>Sim City</i>	1989	Created by Will Wright published by Maxis. A game for planning and building a city. Developed for Amiga and Macintosh followed by PC and Commodore. (http://www.simcity.com/en_US/game/history)
<i>Lemmings</i>	1991	Game for the Amiga by DMA Design. Published by Psygnosis. A game about guiding lemmings through danger. (Randelshofer 2013)
<i>Museum Madness</i>	1994	PC (DOS and Macintosh) game designed by Novotrade, published by MECC. Game is about stopping a virus that is bringing exhibits to life. (http://www.abandonia.com/en/games/479/Museum+Madness.html)(http://www.abandonia.com/en/games/479/Museum+Madness.html)

Table 6.1: Games for learning from the second half of the 20th Century. (Source: <http://www.onlineuniversities.com/blog/2012/09/20-educational-games-that-were-ahead-their-time/>)

There had been a major change to society especially amongst the young with the (Prensky 2001 p.1): ‘arrival and rapid dissemination of digital technology in the last decades of the 20th Century’.

Table 6.1 shows a selection of computerised games for learning that were developed in the second half of the 20th Century: *The Oregon Trail*, *Where in the world is Carmen Sandiego?* and *SimCity 4* have a geographical element to them (Figure 6.14-6.16).

Figure 6.14: *The Oregon Trail*. (Source: <http://www.mobygames.com/game/dos/oregon-trail/screenshots/gameShotId,3584/>, viewed 23 June 2013)

Figure 6.15: *Where in the World is Carmen Sandiego?* (Source: <http://www.abandonia.com/games/13>, viewed 23 June 2013)

Figure 6.16: *Sim City 4*. (Source: http://www.gamefaqs.com/pc/917992-simcity-4-deluxe-edition/images/gs_screen-2), viewed 24 June 2013)

Board based simulation games for business and other purposes have continued to be used but began to be supplanted by initially mainframe computers and then desktop computers. Table 6.2 displays five phases in the development of business gaming up until 2009 (Faria *et al.* 2009 p. 467). These five phases followed a similar path to the development of wargames, and learning games.

Phase	Years	Developments
I	1955-1963	Creation and growth of hand-scored games
II	1962-1968	Creation of mainframe business games and growth of commercially published games
III	1966-1985	Fastest growth of mainframe games and significant growth in business game complexity
IV	1984-2000	Growth of PC-based games and development of decision making aids to accompany business games
V	1998-Present (2009)	The growth of business games on the Internet and run through central servers

Table 6.2: Phases I-V in the Development of Business Gaming. (Source: Faria *et al.* 2009 p. 467)

6.5.3 Simulation and Games for Learning

It was suggested by Gee (2003 p.205) that computer games for learning should work with '*good principles of learning, principles that are better than those of many of our skill and drill, back to basics, test them until you drop schools*'. Various researchers and authors have suggested ways in which these good principles of learning should be incorporated into educational games and simulations.

Writing on educational games and simulations Margaret Gredler (1996) pointed out that some 27 research studies had found no significant difference between delivering a topic by lecture or by simulation when the post- tests focussed on knowledge acquisition. She proposed that a basic framework of games and simulations involves surface and deep structures. The surface structure is the scenario or dataset and the deep structure is the underlying psychologically or cognitive science based framework of the exercise together with the relationships between the learner and the task and the learner and the teacher. In both games and simulations students are in charge of the action and are transported to another world.

She (ibid) divided simulations on the computer into two categories: 1) Experiential and 2) Symbolic. She wrote that academic games should not allow chance to contribute to success in the task, nor use ethically questionable strategies. Decisions on winning should be decided based on problem solving and knowledge skills. Design should also carefully examine the proposed task- reinforcement structure, the role of previous knowledge, and ensure an appropriate complexity of problem solving for the target clients. The cognitive strategies and social interactions should be tested and redesigned if necessary and follow- up research should be carried out on the effects of specific processes used. In addition they should be based on expert knowledge; that random chance should be excluded and there should be an avoidance of zero- sum games. That is a game where there are winners and

losers. This derives from +1 for winning and -1 for losing in a two person game; the sum of both is zero.

Reviewing empirical research on video games and learning outcomes for adults O'Neill *et al.* (2005) defined games and simulations as games with less authentic cause and effect than simulation; a simulation has no set conclusion. Games are win or lose and some games finish in a set time and may declare a draw if no conclusion is reached. A simulation on the other hand has a non-linear structure in contrast to a game's linear structure. A game is playful whereas a simulation is not.

They looked at 19 studies and found most measured and found problem solving occurred, but none measured self regulation, defined as motivation and metacognition. They suggested that because of their playful nature games and simulations should decrease anxiety about learning. However they concluded that the lack of structure or scaffolding for learning in a game is a problem.

Fletcher and Tobias (2006) views echoed those of O'Neill *et al.* (2005) in a research review about computer games and simulations for learning. They concluded that games need to be designed for learning using forms of scaffolding. CODE RED: MOBILE has explicit use scaffolding or chunking in the *Mobile Learning System* framework and the *Bush/Grass fire Schema*.

6.5.4 Key concepts for making the CODE RED: MOBILE test bed

The key concepts for the design of a game framework for the scenario training exercise prototype are presented in Table 6.3. The **GAMEPLAYER** ideas in Table 6.3 informed the selection of *7scenes* as the game framework on the *iPad 3*. It provides interactivity on the *iPad 3*. This interactivity includes the ability to see the location of the participant on the map view of the Hanging

<i>THE GAMEPLAYER</i>
Incorporate <i>gameplayer</i> elements (Cartwright 1999)
<i>Gameplayer</i> interfaces and mechanisms in games are very ancient and people are very familiar with them (Gray 1995)
<i>Gameplayer</i> elements have been used in military training for centuries (Gray 1995)
<i>GAME ELEMENTS</i>
Consider the game as ' <i>a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome.</i> ' <i>Salen</i> and <i>Zimmerman</i> (2003 p. 80)
Games have a story line or narrative similar to the notion that visualisations incorporate a narrative or tell a story (Murray 1997)
Include the concept of OODA Orient Observe, Decide, Act: elements of decision making (Boyd 1995)
Ensure: Flow (Bryce & Higgins, 2000), agency, rapture, attachment, immersion and presence (Murray 1997)
Consider the importance of interactivity (Mortensen 2002; Ryan 2001).
Allocentric perspective views, slightly looking down provide a useful viewpoint (Quinn and Cartwright 2008).
The social, spatial, temporal magic circle of play (<i>Montola</i> , 2005; Huizenga 1955) is a useful perspective on immersion in games
Simulations are non- linear, games are linear (<i>Gredler</i> 1996)
Game elements must be fun (<i>Admiraal</i> 2009)
Early games have strong spatial and temporal dimensions, and early incorporate topographical maps
Computers remove the drudgery out of paper based and some board games
Serious Games and military simulations have used modifications of commercial computer games (<i>McLeroy</i> 2008).
<i>LEARNING IN GAMES</i>
Games for learning need careful scaffolding (Fletcher and Tobias 2006; O'Neill <i>et al.</i> (2005).
Make the game as concrete as possible (Brown <i>et al.</i> 2011)
Use the mobile device to lower cognitive load (Brown <i>et al.</i> 2011)

Table 6.3: Game concepts for the CODE RED: MOBILE exercise.

Rock Reserve. The location of objectives can be seen. Information at objectives can be opened and viewed. The animations and static information resembles information delivery in computer games like *Crysis Wars* (crytek.com). There is a real world training phase before the commencement of the game which resembles what happen in most computer games like *Crysis Wars*.

Participants score points for correct decisions, and get a second chance if wrong, as with many computer games.

The *GAME ELEMENTS* are covered by the design of the unfolding story about the bushfire that develops and moves across the landscape and then suddenly changes direction with the arrival of the wind change. The participants then must then go to the houses in the area and check if they are in the path of the new fire. They then have to decide if the house will burn or not. This basic narrative, developing for the participant a mental model of the landscape at Hanging Rock with a fictional fire burning over it, and the decision making exercise, subsume the game elements decided as critical. This is as concrete as possible and there is little that is abstract in nature and the device carries much of the cognitive load. For example the delivered information can be reviewed, at any time, from any place in the reserve.

The key *LEARNING IN GAMES* concepts include scaffolding the learning, ensuring that the information provided conforms to the pedagogy developed i.e. constructivist with problematising (Andrews and Haythornthwaite (2007), citing Reiser (2004). The information is delivered in the form of a narrative that is received on location as each of the three stages of the fire is reached. The journey to the three locations provides a temporal and spatial scale to changes in the incident which also helps scaffold the event. The walk to the location of the four houses also helps make concrete the location of the houses in relation to the fictional abstract fire. The animations and images assist in making the fictional fire less abstract. The narrative of a bushfire with a wind change that these firefighters will probably encounter, at a location they are familiar with, combines a real place with a fictional fire and is in the nature of an apprentice like training episode.

The armed forces, in particular of the United States, NATO and its allies, with large budgets, have made great efforts to design and use networked games and simulations for training. This lessens the amount of time and money spent on field training, by replacing live units with virtual ones, and by integrating mixed reality combat overviews into maps on computers. The concept of combining live participants in the field with real tools, weapons or vehicles, with real participants in simulators, combined into a constructive view (a computer based overview or map), which may have virtual tools, weapons or vehicles controlled by the computer or a real trainer, is called Live and Synthetic , Live/Synthetic, or Live, Virtual and Constructive (LVS) training. This uses some of the features of games, including many of the ideas summarised in Table 6.3.

CODE RED: MOBILE shares some features with Live/Synthetic training. There are live participants in the real world, whose location is shown in the constructive view of the exercise displayed on the map in *7scenes*. The House markers are virtual objects in the constructive view. The Bushfire media are viewed through selecting the information markers, also in the constructive view. The bushfire media were created in *Sandbox2* and are a simulation of the bushfire, viewed as a movie. The static media is a screenshot of that movie. The media are designed to create a virtual bushfire in the participant's minds, which they have to use to predict which houses will be burnt. The mix is a form of Live/Synthetic training.

6.5.5 Simulations and computer games for training: Live and Synthetic or Live, Virtual and Constructive (LVS)

The United States Armed Forces and its NATO and other allies are developing training that incorporates live deployments of personnel, vehicles and equipment in the field, in combination with personnel operating simulators, i.e. virtual fighter planes. These real and virtual or synthetic elements are integrated into, what is called a constructive view or map on a computer. This constructive map provides an overview of a mixed reality

exercise. Incident commanders and their teams use this map to direct operations but they cannot tell which elements are virtual or real.

In 2007 the *Talisman Sabre* exercise took place in northern Australia with combined US and Australian forces. This was an early example where the concept of Live, Virtual and Constructive (LVC) training was the basis for a Joint Synthetic Training Environment. Wickham & McFarlane (2007 p.1) ‘*Seven simulation systems (two live, four virtual and one constructive)*’ were integrated. Results revealed that LVC enhanced training; interoperability between US and Australian systems was attained, and a major urban operations facility was built.

The *Joint Strike Fighter*, an airplane in development for the air forces of the United States, the United Kingdom, Canada, Australia and the Netherlands. Pilots receive a 50-50 live/synthetic training mix, comprising classroom instruction and simulator training (Quintana, 2013). The aircraft and simulator systems are identical. Pilots are trained to basic competencies on core tasks. In the UK, the Waddington RAF air base provides live air space and facilities for aircrew to train in live and virtual exercises with UK Army personnel.

Col. Gary B. Brown director at the US Army, Combat Training Center, said that (Walker, 2009 para 5): ‘*greater use of blended live, virtual, constructive and gaming training tools will allow the Army to manage limited resources more effectively and efficiently*’.

US Army Network Integration Evaluation (NIE) 14.1 pioneered a combination of live, virtual, constructive and distributed operations in order to increase efficiencies and demonstrate new training techniques.

Approximately 40 percent of the exercise was conducted as a virtual operation, but soldiers participating live could not tell the difference. The size of the forces in the field, were reduced by replacing them with ‘virtual and constructive operations...while still meeting all test and evaluation

requirements' said Brig. Gen. John W. Charlton, commanding general of the Brigade Modernization Command quoted by Heininger (2013 para 11).

The US Army's withdrawal from Afghanistan and the decommissioning of some bases in Europe has resulted in US Army training, in the new strategic situation, relying more on home base training. The Integrated training environment (ITE) blends (Kauchak 2012 p.10): '*LVC gaming training aids, simulations, simulators*'... (and relies on a) '*persistent network that links multiple home stations.*' This provides the US Army with training for complex situations in realistic scenarios.

Figure 6.17: The Training Triangle. Live and Synthetic added by author and diagram redrawn. (Source: Frank, Helms & Voor 2000)

In Figure 6.17 the Training Triangle hierarchy is shown (Frank *et al.* 2000). Training proceeds from the Classroom where there is an introduction to the subject area, to Virtual training, perhaps in simulators, to Constructive training where skills can be practiced at an abstract, administrative or Incident Management Team level, to Live where the skills are rehearsed in the field using real equipment. Synthetic combines some or all of the non-Live aspects of training.

Figure 6.18: Live Synthetic Balance in light of SDR¹². (Source: Dudfield & Kearse 2009 cited in Kirby *et al.* 2011 p.4)

Figure 6.18 illustrates the balance that must be maintained between Live and Synthetic elements, where Live is much more expensive, dangerous and organisationally complex than Synthetic, which is easy to set up, realistic, safer, embraced by the gamer generation and adaptable to individual as well as group training. The utility of the training must also be considered (Dudfield & Kearse (2009) cited in Kirby *et al.* (2011 p.4).

The Network Integration Evaluation (NIE), of the US Army (McCleary) is testing the WIN-T network. This is a network that connects soldiers with headquarters allowing for the transmission of images, text and intelligence from and to the front line. The soldier carries a Samsung Galaxy Note II smartphone that is chest mounted (Figure 6.19). It communicates via usb through the hip-mounted Rifleman Radio. Most of its other communications abilities is erased. The software is US Army designed. This is the Nett Warrior system (Dixon & Henning 2013).

¹² Strategic Defence and Security Review- UK government.

Figure 6.19: The Nett Warrior system displays maps, troop positions and operational updates. Device is the Samsung Note I. (Source: Gourley 2013, p.26)

A Live, Virtual and Constructive (LVC), First Responder/Pararescue Training Research Test bed was described by Whitted *et al.* (2013). This application combined sensors with mobile technology, assisting an Incident Controller's situation awareness in a Tactical Operations or Incident Control centre.

CryEngine was used to integrate Live and Constructive elements of the LVC SIDFOT project. *SCOPE* was the *Google Earth* based viewer for desktop computer and mobile *Android* devices. Here information from sensors, such as detected plumes of smoke, was viewed as an overlay in *GoogleEarth*.

Virtual and real cameras inject visual data into the application. Live data is pushed back into the application to show the location and movements of real vehicles and people. Synthetic people and vehicles are also injected into the application. The live and synthetic entities may be included via the web from remote facilities. Two demonstrations of LVC SIDFOT confirmed that it is a

successful means of integrating live and virtual entities for First Responder scenario training.

AirForce pararescuemen from the Kentucky Air National Guard at Calamityville, Wright State University National Center for Medical Emergencies will undertake a demonstration of LVC training tools in March 2014. The pararescue participants will carry sensors that enable their embodiment in a virtual world. The mission will be recorded for debriefing (Hannah 2014).

Map overviews of fires in CFA/DEPI Incident Control Centres in Victoria are provided, in 2014, by *eMap*- a product of CFA and DEPI, based on *Arcmap* (esri.com). It is used to map and predict fires and locate aerial and some ground assets. In late 2014 the new digital radio network will map all vehicles through digital radio handsets. CFA/DEPI exercises in late 2013 involved ground observers reporting about a virtual fire from the field to the Incident Management Team at the Gisborne Incident Control Centre (ICC).

In the future, in a similar exercise to First Responder/Pararescue Training, ground observers and other assets could be mapped through their digital radios. The location of live (real) assets could be integrated into a Live/Synthetic exercise using the constructive view provided by a revised *eMap*. This would provide the CFA/DEPI with a framework for Live/Synthetic training for ICC and firefighters simultaneously.

CODE RED: MOBILE features the Learning Triangle (Figure 6.17) concepts of Frank *et al.* (2000) with a classroom like introduction to the exercise. Skills in using *7scenes* and the *iPad3* were acquired and practiced. As firefighting becomes more digital these sorts of skills will be needed. Skills in utilising virtual views of a bushfire in order to practice fire prediction were practised. The constructive level was used by participants when they locate themselves on the map in relation to topographic features, and to the markers that delivered information or tasks. They also used the constructive element i.e.

the 7scenes' *Googlemap* to orient themselves to the virtual bushfire and its movements.

6.6 Chapter summary

In chapter six we have seen that games of various types have been played by people since earliest times. There is often a competitive element whether between people or with inanimate events such as disasters. Military games have a long history leading to, in recent times, the development of serious games where the main aim is not so much fun, although that may still occur, but for various types of training or learning.

Computerising games removed much of their less compelling aspects and enabled the delivery of games with realistic visuals and quick and fair outcomes for players' decisions. Games, and this applies also to serious or training games, can through the narrative and interactivity provide feelings of flow, immersion and presence. These emotional states assist the participant in imagining the fictional bushfire or other event as a threat that must be dealt with.

Pervasive games were introduced as types of game that can take place anywhere the real is combined with the virtual. Location based games go further, and the location of the game is the setting, and objects in the space characters in the game narrative. The *Game of the Goose* (Figure 5.10) was an early manifestation where the locations are linear and not real in a concrete sense, as is the Egyptian game *Hounds and Jackals* in Figure 5.1. In 1768 John Jeffery's game departed from this pattern and the locations were of real places and the journey although returning to the origin followed a realistic course.

The invention of the mainframe computer improved the predictive power of simulations but when the desktop computer was invented this power was available to a mass market. Games which were formerly played with a board and pieces were ported to the desktop computer.

Games for learning which had been useful and engaging as board games or simulation games could now be played on the computer and were more engaging with sound, movies, and high quality images. Scholars reported that games must be scaffolded if they were to be used for learning.

Games for mobile devices and learning games that utilise the location of the player were developed. *Mscope* is an example of a game editor and application for a mobile device.

In chapter four the examples of Admiraal (2009) and Brown (2011) were provided to illustrate how learning objectives can be achieved with mobile location based devices and applications. *Frequency 1550* (Admiraal *et al.* 2009) is a history learning game for secondary students and *RouteMate* a training game for people having difficulties remembering their way to work or school. Both use constructivist pedagogy, though cognitive apprenticeship is seen more in *RouteMate*. These two key examples are exemplars that inspired the design and development of CODE RED: MOBILE.

CODE RED: MOBILE has LIVE features with participants moving in the real world whilst being tracked in *7scenes* which provides the Constructive view. The dynamic-static annotated movies and annotated static screenshots of the fire, made in a computer game editor based simulation, and available on location in *7scenes* means the bushfire is a virtual element of the exercise. The four houses are also virtual elements. Thus Live, Virtual and Constructive elements are present. CODE RED: MOBILE is a form of Live/Synthetic mobile training exercise. In chapter seven the *Mobile Learning System* for CODE RED: MOBILE is introduced together with development of the virtual bushfire. This is followed by the development of the Mobile Game design, together with some details on the acquisition of participant's GPS tracks and methods used to clean up corrupted tracks.

Chapter 7

CODE RED: MOBILE a Live/Synthetic test bed

Figure 7.1: Participant, beneath black arrow, in orange CFA personal protective clothing, near Hanging Rock during the CODE RED: MOBILE exercise, May, 2012.

7 Chapter overview

In this chapter the construction of the CODE RED: MOBILE testbed and the training exercise are described. The design is based on theory garnered in the previous chapters on bushfire theory and practice; a pedagogy for mobile learning based on constructivism and scaffolding; media theory research that promoted annotated dynamic-static movies and static images as a good way to learn about complex topics; game theory provided evidence that mobile game-like learning with Live/Synthetic features is good practice in complex

field- based training. This provided a basis for answering the broad research question asking for the best approach to deliver training using visualisations in a mobile training exercise: **Q.1 *How can a conceptualisation of a bushfire, as visualisations in a game framework on a mobile device, best assist with the understanding of a virtual bushfire and enable decision-making about its behaviour in the real world location?***

7.1 Conceptualising and making CODE RED: MOBILE

A grass or bushfire burning southwards, on a hot dry summer's day in the State of Victoria, develops long flanks with a relatively narrow head. Often, on the hottest days in the late afternoon, a cold front or upper level trough will cross the State from west to east. As it passes an area like the Macedon Ranges where a large fire may be burning, the eastern flank will become the head fire, and this new very wide fire front burns eastwards. This scenario is the narrative of the CODE RED: MOBILE exercise. In chapter one the basic course in *Wildfire Firefighter* for 'Minimum Skills' was outlined and the CFA Skills Maintenance Drills. However the dangers of a wind change were not emphasised in the Skills Maintenance Drills. In addition, as one of its recent policy introductions in the training area, it was noted by US Army's General Dempsey (2011 Foreword) that for training they would focus on: *'opportunities presented by dynamic virtual environments, by on-line gaming, and by mobile learning.'* The emergency services in Australia may also be exhorted to consider this as a focus for training policy.

7.1.1 CODE RED: MOBILE as a *Mobile Learning System*

Designers of mobile location based services and learning systems should be aware that a cognitive artefact is being constructed. Its parts must not overload the mind and they must join together in a conduit between the real world and the mind, simplifying and reformulating entities, events, purposes and processes so as to flow with little effort into the working memory. Those ideas and information should then be available for understanding problems and decision making. In this section we look at some examples of frameworks

developed for mobile location based services that provide a model of a framework for a *Mobile Learning System* such as the prototype CODE RED: MOBILE.

A framework for mobile geo-services that use the internet to access information for spatial tasks was provided by Dransch (2005). She wrote that mobile geo-services use a geographical positioning system or cell tower locations for finding a user's location. The user can find services that relate to their location. The provision of useful location-based services requires understanding the user: who they are; tasks they might wish to perform and problems they may want to solve. Thus a range of data and services needs to be prepared for the user in a workable framework. Dransch (2005) further suggested using a scenario to develop mobile geo-services. The goals, sub goals and actions or process for determining the route of a pipeline were used to plan how mobile geo-services would be delivered by the mobile devices in a network. The use of a scenario required understanding the context of a problem and the devices you would use in order to design the system and what it delivered. Similarly with CODE RED: MOBILE, where a scenario with a contextual problem requires decision making. This also required the design of the system within which it will be delivered; the subject of this section of the chapter.

The technology, pedagogy, content and knowledge framework (TPCK) for learning using technology, was introduced by Mishra and Koehler (2006). Shulman's (1986) original concept was termed PCK (*pedagogy, content and knowledge*¹³). Mishra and Koehler's framework added technology, resulting in the TPCK framework. TPCK emphasises that teaching or training requires that we must take into account not only the content and pedagogical processes but also the *technology*.

In this context the *pedagogy* for CODE RED: MOBILE is constructive learning (Bruner 1973) with scaffolding (Kearsley 2012, Andrews &

¹³ In Schulman's (1986) terms the *knowledge* of the teacher, organisation or culture as against the actual *content* of instruction.

Haythornthwaite 2007) or chunking (Gobet *et al.* 2001, Miller 1956) and cognitive apprenticeship (Collins *et al.* 1989), as well as problematising (Andrews & Haythornthwaite (2007) citing Reiser 2004,). Winn's (2003) idea that cognitive science was the key to learning and instruction, rather than Activity Theory with its considerations of social structure (Squires 2002), was preferred as the basis of a pedagogy for CODE RED: MOBILE. The *content* includes the maps and visualisations of the bushfires as well as 'Minimum Skills' information from the CFA publication *Wildfire Firefighter Learning Manual* (2006) and the *Skills Maintenance Drills* (CFA 2012). The *technology* is the *iPad 3*, the GPS, *Sandbox2*. *Location based technology*, including the internet and the affordances of *7scenes* (7scenes.com).

The *knowledge* that informed the *content* is derived from many researchers, firefighters and community members with their experiences of local conditions and fire histories.

Figure 7.2: Framework for a *Mobile Learning System*. CT= Conversation Theory, CS=cognitive science, C= content, P= pedagogy, LBT= location based technology, K = knowledge, MLS= Mobile Learning System. (Quinn & Cartwright, 2009)

A framework (Figure 7.2) for the design of lessons and training using mobile devices may be assisted with changes to the TPACK framework using the ideas outlined above with additions from cognitive science and Conversation Theory. In this Mobile Learning System framework cognitive science and Conversation Theory combine to form a new pedagogy. This pedagogy combines with the required content to create knowledge in a context suitable for learning. The knowledge is delivered in CODE RED: MOBILE with location based technology to make a *Mobile Learning System*. This provides a learning framework for CODE RED: MOBILE (Quinn & Cartwright, 2009). Having decided on the structure of the learning framework we must now look at the content that is to be delivered with the *Mobile Learning System* outlined above.

7.1.2 The *Bush/Grass Fire Disaster Schema*

The Bush/ Grass Fire Disaster is schematically illustrated in Figure 7.3. Very dry conditions in the forest and grassland in combination with an ignition event and strong dry winds can sometimes result in major disasters

Figure 7.3: The *Bush/Grass Fire Disaster Schema*

and great loss of life after a wind change. The *Bush/Grass Fire Disaster Schema* may not reflect the real mental model in a human mind, but is useful in that it visualises the causally linked ideas that form the basis of understanding a wind change based bushfire disaster. The ‘*how?*’ and ‘*why?*’ boxes in the diagram are where the causal chain is understood through observation and inference. Those are also the points where the chain can be broken. Ignition of a grassland or bushland can be stopped by keeping track of arsonists, or by declaring Fire Ban Days. The effects of a wind change can be minimized by heavily attacking the flank of the fire that will become the head fire after the wind change. Major fires can be lessened by better town and rural planning together with well planned fuel reduction burns. Firefighters would be expected to have a mental model or cognitive map of fires resembling the *Bush/Grass Fire Disaster Schema*. It conforms to the ideas from cognitive science that our working memory can only be conscious of a limited amount of items at one time with a limit of four for many people (Sims & Hegarty 1997, Baddeley 2002, Cowan 2000). This is the prime purpose of cognitive artefacts as they enable cognitive offloading to lists, pictures, maps and so on.

This model of a bushfire event derived from the bushfire schema, and delivered in the *Mobile Learning System* provides schema for conceptualizing a virtual bushfire at a real location. This, it is proposed, is something like the basis of an expert’s mental model of the scenario bushfire, that CODE RED: MOBILE imparts to the participants, through the displayed media, at various locations. The intention being that this concept of the fire, at its real world locations, is used by the participants to learn, what it is proposed happened in the fire, and to make decisions based on that knowledge.

The next section examines how the conceptualization fire embodied in the *Bush/Grass Fire Disaster Schema* was used as the basis for the concept and design of the bushfire in the CODE RED: MOBILE exercise.

7.2 Creating the scenario

7.2.1 Modelling the scenario for the exercise location

The bushfire is set at the Hanging Rock Reserve, near Newham, in Central Victoria (Figure 7.4).

Figure 7.4: Location Map of Kyneton and Hanging Rock. Base map source: Wikimedia.

7.2.2 Creating a realistic bushfire at Hanging Rock with *Phoenix RapidFire*

Fire Behaviour Analysts, at the State Control Centre, use *Phoenix Rapidfire* (Tolhurst *et al.* 2008) to predict the outcomes of fires. The author is qualified to Intermediate Level FBAN and was mentored for 4 days at the State Control Centre in early 2011, and trained in the use of *Phoenix Rapidfire*. Figure 7.5 shows *Phoenix RapidFire* with the weather tab open.

Figure 7.5: *Phoenix Rapidfire* application displaying the weather for the Rogers Drive Fire.

The weather details (Figure 7.5) for the Rogers Drive Fire near Kyneton (Figure 7.6) on 26th February, 2012 and into the next day are shown in the spreadsheet in *Phoenix Rapidfire*.

Figure 7.6: Location Map for Rogers Drive and Hanging Rock. Base map source: *eMap*.

This weather data was a basis for the Hanging Rock fire in the CODE RED: MOBILE scenario training exercise. The weather that is current for a location, and the predicted weather for a length of time set in *RapidFire*, by the FBAN, is used for a fire spread prediction. The predicted fire behaviour can be exported as a .kml file and opened in *GoogleEarth*. Pyrocumulus clouds are viewed as an animation.

In Figure 7.5 the window shows the application's data entry spreadsheet with the weather data columns. The columns for time and temperature can be seen. In the online version of *Phoenix Rapidfire* the weather data for a specified number of hours downloads directly from a Bureau of Meteorology service when predicting a current fire at a specified location. The resulting spreadsheet data can be edited to test other locations and changes in weather, such as various possible times for the wind change. Thus a fire can be manipulated using the spreadsheet, changing the temperature, humidity and wind speed and direction. In Figure 7.5 the weather data in the visible spreadsheet for the 'Rogers Drive' Fire has been altered by entering new wind direction bearings for the prototype CODE RED: MOBILE exercise.

The author had made the original Rogers Drive Fire, fire prediction when at the Gisborne Incident Control Centre at Gisborne, on the day of the fire, when on duty as a Fire Mapper. The mapping program then used was *Emergency Information Management System (EIMS) Mapper*, a DSE/CFA application. (This application was superseded in 2013 by *Emergency Map (eMap)*).

In early 2012, at the State Control Centre, whilst being mentored for the Fire Behaviour Analyst role the opportunity arose to check the author's computer drawn predictions for the Rogers Drive Fire against *Phoenix Rapidfire's* prediction. This prediction was more detailed as it had taken account of wind direction records that were not available at the Gisborne ICC. *Phoenix Rapidfire* was then used to create a fire prediction for Hanging Rock using the 'Rogers Drive Fire' weather data.

Whilst experimenting with the Rogers Drive Fire at the State Control centre it was discovered that the fire would not burn over the paddock to the east of the Racecourse at Hanging Rock. The fuel type for that paddock was set for zero fuel load- there was nothing to burn, so the fire would go out in *Phoenix Rapidfire* but not, of course in reality. This was worked around by moving the fire location near to Hanging Rock, where there was a similar fuel load and mix of grassland and bush. Rerunning the prediction in *Phoenix Rapidfire* produced the fire at the new location. The isochrones graphic could be copied in *Google Earth* and then edited to produce a graphic with a transparent background using *Paint.net*¹⁴. The new image could then be placed at the correct position at the Hanging Rock Reserve in *Google Earth*.

In Figure 7.7 the fire isochrone lines for the Rogers Drive Fire are apricot coloured. The set of red isochrones lines are the orange/apricot prediction isochrones moved and rotated to a new position on the Hanging Rock racecourse for the CODE RED: MOBILE fire. The purple squares for the adapted Rogers Drive Fire show areas of the fire that have gone out by the end time of the fire prediction. Bright yellow represents low flame heights of 0.27 metres. Dark yellow is 3.6 metres and the intermediate yellow is 2.4metres high. These flame heights could then be used for the *Sandbox2* dynamic-static movies and static screen shots of the CODE RED: MOBILE fire.

¹⁴ A free image and photograph editor designed by Rick Brewster . Source: <http://blog.getpaint.net/2010/04/25/paint-net-v3-5-5-is-now-available/>

Figure 7.7: In *Google Earth* (2013) the apricot isochrones show the one hourly location of the fire front predictions for the adapted Rogers Drive Fire. Red isochrones show the CODE RED: MOBILE exercise fire.

Figure 7.8: *Phoenix Rapidfire* fire prediction for CODE RED: MOBILE exercise at Hanging Rock. Red lines are isochrones showing limit of fire at the marked times. The background of the *Phoenix Rapidfire* map was made transparent and overlaid onto *Google Earth* (2012).

In Figure 7.8 fire front isochrones have been overlaid onto *Google Earth*. This map with a transparent background was a *Phoenix Rapidfire* prediction for a close by area to Hanging Rock. The map has been shifted onto the CODE RED: MOBILE exercise training area. The fire prediction had to be made at a nearby area because trials had shown that the fuel load database recorded for the eastern paddocks of the Hanging Rock Reserve had a reading of no fuel i.e. it was similar to a bitumen road or concrete slab. Fires would not burn according to *Phoenix Rapidfire* onto the paddocks to the east of the racecourse area. The fire prediction map for Hanging Rock was made at a very close by area with similar fuel load, vegetation and terrain. The state fuel load database has errors in it. Indeed all predictive maps have to be approved by a qualified fire behaviour analyst (FBAN) before publication or use, in order to check for errors.

In Figure 7.8 times have been added to the isochrones. This shows the fire travelled at approximately 250 metres each hour. This fire would be relatively easy to put out. The participants in the exercise could walk much faster than the Rogers Drive Fire. The movies of the fire show the position of the fire front. The fire front although appearing very active does not travel over the ground in the *Crysis Wars* editor. The movie and the static screenshots indicate with the tilt of the flames and the direction of the smoke which way the fire is travelling. The three positions for participant's information media, in *Phase 1* of the exercise, where they learn about the fire, are located at the three stages of the fire. Group 1 and Group 2 have separate information treatments and locations where they view the information. As Group 1 and Group 2 participants walk between each of their group's three locations, the elapse of virtual time is always the same as real time. They do not know what the speed of the original fire was. As they reach the second marker the virtual fire they see has moved to the second marker. A slow or fast walker sees the fire change at the marker location and assumes that their rate of movement is the same as the fires. In other words as they walk from their group's first media position to the second in a southwards direction, the virtual fire has

moved same distance as they did. Thus their real pace of walking is the speed the virtual fire front moves.

To summarise, the exercise was about a fire affected by a wind change. A bushfire was developed by adjusting wind directions at certain times in the data entry section of *Phoenix Rapidfire*, a program used routinely to predict the course of real fires by Fire Behaviour Analysts in the State Control Centre.

With the fire determined the 3D scene was constructed and the movies made. These would approximate the flame heights in the *Phoenix Rapidfire* prediction output. The elements of the fire in the 3D scene would match photographs of real fires and their behaviour follow the information in the diagrams from the *Wildfire Firefighter* (2006) CFA training text. The next section looks at how the scenario and the materials including the 3D model of Hanging Rock with a bushfire undergoing a wind change were made.

7.3 Mobile game design for the exercise using 7scenes

Virtual bushfires on a mobile device in the matching real terrain add impact to scenario training exercises in the field. The *Crysis Wars* editor although not producing physically accurate models can display visually useful facsimiles of real bushfires and their features. These simulations of fire recorded as movies and screen shots from those movies were used as virtual elements for the Synthetic aspects of the training exercise. The virtual bushfires or geovisualisations were trialled with firefighters from the Mountain Group Brigades using a location based mobile training scenario called CODE RED: MOBILE running on GPS-enabled *iPad 3*. Ten *iPad 3* were loaned for a month by the Apple University Consortium. The experimental location was the Hanging Rock Reserve near Mt Macedon in Central Victoria. The experiment is described in greater detail later in this chapter. The mobile game framework was provided by 7scenes (7scenes.com). Figure 7.9 displays the screen just before the exercise began and the markers

are coloured blue. After the game is started in *7scenes* the markers are coloured by their function.

Figure 7.9: View of the CODE RED: MOBILE markers before commencement of the exercise in the *7scenes* application on the *iPad 3*. Hanging Rock is near the centre of the image.

The scenario in *7scenes* was typical for a hot windy summer's day in Central Victoria, Australia. It simulated a bushfire burning southwards through lightly treed areas of the local racecourse that is situated at the eastern side of the Hanging Rock Reserve. An aerial view of Hanging Rock and the racecourse to the left (covered with blue markers) can be seen in Figure 7.9. Later in the day a wind change turned the fire eastwards. The visualisations and other information were delivered to the device when the player entered a GPS defined location. This is characterised as a form of location based service. The visualisations for CODE RED: MOBILE were created in *Sandbox2*, the editor that is included with the *Crysis Wars* computer game (crytek.com). This game editor and game has been acknowledged as a viable

means of creating geovisualisations. Quinn and Cartwright (2011) have described how visualisations about bushfires for a mobile device, can be made in the *Sandbox2* editor.

7scenes is a user friendly editing application for location based tours and other genre, the free version is the *Sightseeing* genre. It has limitations but these can be overcome to some extent as will be outlined. In Figure 7.10 the *Google Map* background for an area close to Hanging Rock is displayed. In the

Figure 7.10: The *7scenes* editor (7scenes.com).

top right corner in the black console can be seen five of the seven types of tags or markers that can be used. The five visible markers are Note and Video, Combo, Opinion and Task, the other two markers Sound and Photo can be made visible by selecting the left side arrow.. The combo marker allows photo, movies and sound to be added in a type of slide show. Photo types are jpg, gif and png. Movies are mp4, mov, 3gp and flv. Sounds are mp3. CODE RED: MOBILE used .png for images and .mp4 for movies. The combo marker was very useful as it provided a means of delivering the information as a mixed media presentation with images of maps and movies made in *Sandbox2*.

In Figure 7.11 the available collection of movies (created by the author) is seen in the lower, black framed window. Movies can be uploaded from an internet connected computer. The movie, after upload, is dragged into the + area of the blue framed window (above the upload label in the black framed window) which adds it to the movie marker (with a movie camera logo). The movie marker that is getting the selected movie is just to the left of the movie collection window. When a participant selects that movie marker in *7Scenes* the selected movie plays on the *iPad 3* screen.

7.3.1 The scenario for the exercise in *7scenes*

Figure 7.11: Screenshot of introduction page to CODE RED: MOBILE. (Source: <http://7scenes.com/projects/code-red-firefighting-training-tool/>, viewed 24 June 2013)

Figure 7.11 displays the image of the introductory screen for firefighters taking part in the CODE RED: MOBILE exercise that is also displayed on the 7scenes.com website. The inset map indicates the location of the fire with red

and pink ovals showing the progress of the fire at successive times, in the green area of the map of the Hanging Rock Reserve.

As the fire spreads to the south onto the racecourse, into the grassland with scattered eucalyptus trees, it assumes an elliptical shape typical for a fire under the influence of a strong northerly wind on a hot summer's day. The flames are bent over to the south with a flame height of about 1.5 m. The fire in grass and sparse bush with some taller gum trees then burns further south driven by the strong north wind. This narrow fire burns to the east of the lake at which point a wind change from the west turns the fire so that it burns to the east rather than to the south (Figure 7.12).

Figure 7.12: Wind change drives the fire to the east of the Hanging Rock Reserve. (Source: annotated map from digital version of Spatial Vision's VicMap book ed. 2, 2008)

The western or right flank (from the point of view of someone standing with their back to the point of origin) goes out as it burns onto the blackened burnt out area. The left flank of the fire to the east burns into the paddock to the east of the racecourse. This left flank, if no fire suppression activity has taken place, burns along its entire length towards the east, from near the point of origin to the north, down to the south where the head of the fire had been. The fire which had had a narrow head and was burning southwards now has a wide head burning east.

The landscape of the Hanging Rock Reserve had to be examined in relation to the fire's progression. The position of the lake, the fences round the racetrack, the location of paths and gateways, the watercourses, ditches and bridges or crossing points, and at the time of the exercise, the drainage works on the track itself, needed to be considered as obstacles, dangers, open areas or pathways. The Macedon Ranges Shire Council instructed that no one was to walk on the racecourse track, except at specified crossovers, as drain laying works were in progress at the time of the exercise. Safety was paramount as was ease of passage through the landscape. Iconic features such as the edge of the lake, which was full of water at the time, the island in the lake, and the fishing pier provided landmarks for finding one's position in the reserve.

This was not done explicitly, but if the real scene shows the Fishing Pier to the right of a scene in the visualisation, one knows that people will look at the real terrain, and use features in the landscape to match the real view with the virtual one. Hence one or two at least of this key set of iconic features were always to be seen in the dynamic-static movies or static screenshots of the visualisations of the virtual bushfire.

The *iPad 3* view of 7 scenes was set so that the map would not rotate with the device. The top of the screen was always north. It was found too disconcerting in a trial run to allow the map to orient itself to the participant's travelling direction as it was too sensitive to the walking motion.

With the fire direction, speed and severity decided upon and areas of the reserve that needed to be avoided or utilised determined, the broad outline of the physical setting of CODE RED: MOBILE was ready for the next stage of the design process. At this point a narrative needed to be created, a dramatic incident, a problem or complication that needed to be solved with a beginning, middle and an end in Aristotle's terms (Poetics 330 BCE).

CODE RED: MOBILE incorporates many of the above ideas. Visualisations are conceived of as cognitive artefacts, and engaging with them is a form of conversation with the embedded, structured ideas and information. The

exercise for firefighters delivered information about a bushfire and wind change in a first phase of the exercise followed by a second phase where decisions were made based on that information.

7.3.2 Editing 7scenes for the CODE RED: MOBILE exercise and experiment

At this point it is necessary to provide an outline of the prototype CODE RED: MOBILE exercise in order to explain the set up of information and task delivery in the game-like application *7scenes* on the mobile device. A more detailed account of the experiment is provided in a later section in this chapter. The firefighters were volunteers from the CFA Fire Brigades in the Mt Macedon Group. They were all fit, local, qualified firefighters who had undergone the wildfire Firefighter 'Minimum Skills' training. There were many who had much higher qualifications but these were not recorded. 3 women took part but are not identified. The Ethics Approval application did not ask to record personal details of any of the participants.

For each session, the firefighters were divided into two groups: Group 1, who received maps and the visualisations of the virtual bushfire as annotated screenshots and Group 2, who saw the same maps and the virtual bushfire as movies with the annotated screenshots spliced into the movie. Thus Group 1 saw static media and Group 2 saw dynamic-static media (Pfeiffer *et al.* 2009, 2011). These two treatments were compared in the experiment with the scores participants achieved on various tasks and to a study of their GPS tracks.

Hanging Rock itself can be seen throughout the exercise and is a prime means of finding one's location. The images, both static and dynamic, featuring the bushfires include iconic features such as Hanging Rock, Mt Macedon, the fishing pier, the race callers tower (Figure 7.13 centre image), the dam at the centre of the racetrack and the racetrack fences. These provide spatial information for the participant to locate themselves and the virtual bushfire in relation to the markers on the map and to the real world. The

information phase of the experiment instructs about the bushfire but also orients the participant in the Hanging Rock Reserve.

Figure 7.13: Left to Right: Hanging Rock; race caller's tower to right of middle image and the Fishing Pier. (Source: photographs, May 20 2013 by author)

Participants received a plain language statement of what was involved and signed enrolment forms. This was followed by up to 45 minutes of instruction on how to use the *iPad 3* and *7scenes*. They received a booklet summarising these instructions and carried it with them during the exercise. The field part of the experiment took up to about an hour and a half. Originally there were more tasks to perform but these had to be eliminated after a trial with two non-firefighter, fit adults, one male and one female. This took place on a cold, overcast, rainy day, typical for the district and the season, and showed that the exercise was too long and too exhausting, especially in wet and windy weather. The actual experiments, with a shortened set of tasks, in May, 2012, all occurred on drier less windy days, a rare occurrence in late autumn, at Hanging Rock.

7.3.3 Phase 1: information delivered to Group 1 and 2

Group 1 and 2 took separate routes around the racetrack looking at 2 separate sets of the information media. Group 1's route was to the west of the lake, and Group 2's to the east of the lake (Figure 7.13). On the first day's session there was some confusion as to where to go and people had to be helped in the field. For the second day, a printed map shown in Figure 7.14 was provided.

Figure 7.14: The Information Phase, *Phase 1* is blue for Group 1 and yellow for Group 2. The Decision Making Phase, *Phase 2* for both groups is the green area of the CODE RED: MOBILE exercise. The blue dot near the bottom was the start and finish.

This explicitly showed the two groups where to go for the *Information Phase*, and saved a lot of walking to help people who were in the wrong area. The Blue and Yellow bounded areas are where *Phase 1* information is received at the markers for Group 1 and 2 respectively. Each participant had to go to the real world location of their group's three markers in order from North to South. The markers positions could also be seen on the *Google Map* of the Hanging Rock Reserve displayed in *7scenes* on the *iPad 3* screen.

The shared green marker (in the green line bounded area) asked participants to predict which house(s) would burn after the wind change. The green bounded area is the task area, or *Phase 2* and the four House Markers can be seen from top right to bottom left (numbers 1-4). The BBQ area which is the start and finish is marked by a blue dot to the right of House Marker 4 at the bottom left. A blue sphere shows the participant's position. The lake at the centre of the racetrack is mostly an ochre colour as the satellite image dated from before the end of the last drought and there was little water in the lake. During the exercise the lake was full (See the right hand image in Figure 7.13).

The participants were asked to get as close as they could to the point at the base of the virtual markers (Figure 7.14) in order to see the media at the location the 3d scenes made in *Sandbox2* represented. Some participants did not get close to the specified markers, despite being asked to do so. They were able to open markers from long range enabling them to review previously seen information again.

7.3.4 Group 1's Static Media

Group 1 received the static media. In Figure 7.15 the screenshot of the *7scenes* editor on the *7scenes* website (7scenes.com) displays the media for Group 1 participants at the first location. This is close to the point of origin (POO) of the fire. Note the media on the *iPad 3* is shown full screen, either in landscape or portrait view. The participant's finger swipes the slider under the slide show window to move between the first slide shown on the left to the one on the right. In Figure 7.15 the window showing the image and text has a point under it, like the bottom of a plant label. This marks the location for viewing the information.

Figure 7.15: Group 1: location 1 for static annotated media and text for Point of Origin of Fire.

Figure 7.16 displays the information delivered at the second information location for Group 1 to the south of the Point of Origin information. The fire has been travelling for 3-4 minutes. Media is a slide show with two images side by side and some text below.

Figure 7.16: Slide 1 at the second location for Group 1 with slide 2 to the lower right.

Figure 7.17: The third location with slide 1 for Group 1 on left, slide 2 to the right above and slide 3 showing the map below.

Figure 7.17 shows the static media for the final third stage of the fire where the wind change has arrived with the result that the fire is now turning and will burn to the east impacting areas to the east of the racecourse.

7.3.5 Group 2's dynamic-static media

In Figure 7.18 Group 2 listened to a movie with a narrated account and text about the origin of the fire.

Figure 7.18: Group 2, location 1. Narrated video at Point of Origin of the fire.

Group 2 participants then walked down to location 2 to view the media in Figure 7.19.

Figure 7.19: Group 2, location 2. Movie to the left and map to the right.

The Firefighter participants of Group 2, after looking at the information at location 2, walked to the marker at location 3 displayed in Figure 7.19. At location 3 they found out how the wind change affected the fire.

Figure 7.20: Group 2, location 3. Movie to the left and map to the right.

7.3.6 Phase 2: Decision Making

In the second half of the exercise in the Decision Making Phase, *Phase 2* participants had more freedom to decide their route as the next set of markers were common to both groups. Group 1 and Group 2 participants here go to the same markers. Their first common marker was coloured green in *7scenes*, which upon opening asked them to go to the four blue task markers (with a pen icon) representing virtual houses. It did not specify an order in which to see them, nor give any directions. The green text marker can be seen in Figure 7.20 in the image to the left, under the media window. Opening the green marker reveals the rules for the task (Figure 7.21).

Figure 7.21: The information for *Phase 2*.

These four virtual houses were located on a map of the Hanging Rock area in the *7scenes* application (7scenes.com). The House 2 question in the *7scenes* editor is shown in Figure 7.22. It nearly fills the screen on the *iPad 3*. There is a section beneath that, which is not seen in Figure 7.21, where the participant is invited to type in yes or no to the question 'Will this house burn after the wind change'. Verbal instructions in the briefing before the exercise commenced, reinforced the idea that the fire must be very likely to destroy the house, before one would select yes as the answer to the question.

Figure 7.22: The House 2 task.

The houses were represented by the standard *7scenes* markers. Participants, reaching the real world locations indicated by a House Marker on the map, were presented with the question on the *iPad 3*, asking them if that house would most likely be burned down by the fire or not. Participants typed in their answer, which was recorded to the *7scenes* server, and retrieved by the researcher later. Participants instantly received a score of 10 if they were correct, and then given a second chance if incorrect. They could then gain a score of five if correct at the second attempt. However, in fact only the first score was counted for the purposes of the experiment. This meant that participants knew at each marker whether the fire had definitely been there or not no matter whether they had got it right or wrong on the first attempt. If the participant had understood the maps and media, all the House tasks

should be correctly chosen on the first go. If not, then they should at least get it right on the second attempt. From knowing the correct answers to the House Task they could figure out where the fire had gone and which houses were destroyed. Thus they would not need to have understood the media illustrating where the bushfire had travelled and therefore which houses were most likely burnt down. Only House 1, to the north east was destroyed, the other three survived.

A participant may have gone to House Marker 2 first. They may have thought House 2 would burn, which was wrong. After a second attempt they would know House 2 did not burn. If they had learnt nothing from the media then they still would not know if House 1, 3 or 4 had burnt or not. If they then went to House 1 to the north of House 2, they may have got House 1 wrong as well by choosing that it had not burnt. Once the true results of House 1 and 2 were known then they should have figured, by inference, that 3 and 4 are untouched by the fire. Only a quite confused participant would not get House 3 and 4 correct on the first attempt, after seeing the results of House 1 and 2. Thus most participants should get at least two out of the four House questions correct on the first go, even by random guessing, as the odds are 50:50. Participants who received 100% for the House Task had 4 correct answers for their first go on the House Task and were using the media and not engaged in a deductive exercise using the response to their incorrect answer(s) to the House task. Anyone with 75% had one wrong answer on their first go and most likely, they misjudged how far south the fire went if this was for House 2, and they were using the media to make their judgement on where the fire went after the wind change. Those with below 50% may have been deducing from the feedback, however they may also have been picking answers randomly. This would lower the validity of this test to determine whether dynamic-static media is superior for learning to static media. The final results indicated no difference between the media treatments so this remains a moot point. After the exercise in a debrief type

morning session and the other the afternoon session. They needed to be separated.

The leftmost track is highlighted in yellow-green is Group 1 by selecting the track with the information button. This distinguishes it from the Group 2 track to the right which is a thin black line. The small open window to the top left has had the vertices button selected for the Group 1 track and the GPS data is shown in the bottom right window. This data was then copied to the clipboard using the button in that window's lower bar. *Microsoft Word* was opened and the data pasted there. In *Microsoft Word* the 'Find' function was used to locate 0000. There were many more zeroes for some cases but using the find function asking for four zeroes, the long string of zeroes could be found in the spreadsheet. This set of zeroes indicated that something had interfered with the recording of the GPS signal. The zeroes can then be selected and erased. The next set of 0000 is selected and the process continues until all the errors are deleted in the GPS record.

The resulting cleaned data was then saved as text file and using *Microsoft Excel* saved as a tab delimited file (txt) and a comma separated file (csv). This prepared the files, respectively for the fractal analysis and the spatial temporal analysis using *Geotime 5.3* (oculus.com).

In Figure 7.24 the GPS track is being prepared for splitting. The second half of the exercise was the *Decision Making Phase* or *Phase 2*. The track for *Phase 2* was split from the overall track. This split happens at where the participant had finished reading the *Task Marker* information and was starting to move. This is revealed in the speed column as the participant goes over a speed of 0.0 km/h. It was a little difficult to tell exactly when and where some participants set off to commence *Phase 2* as there was a certain amount of reorientation needed, as revealed by the mapped tracks.

Figure 7.24: *Global Mapper V.13*, selecting stop time.

In Figure 7.24 *Global Mapper V.13* is open and the Feature Vertex list has been selected. Right clicking on any line of data in the window reveals a choice that allows the user to add a time stamp, speed, heading and elapsed time information. This is seen in the open window to the right in Figure 7.24. The selection also reveals the location on the track of that line of data on the map. This is marked by the red circle overlaid on the yellow highlighted line. This is shown on the map in Figure 7.24 just below the lake at Hanging Rock. By scrolling through the data list one can find records which show zero speed. If there are many lines of data at near zero speed for a fair length of time then this is the location from which the participant commenced *Phase 2*. The red circle on the map corresponds to the selected line of data. The red dot was also visually inspected for its general location to make sure it was near the Task Marker. All the GPS track data was saved to *Excel* previously. The index number for the line of data that marks the beginning of *Phase 2* is the same index numbered line in *Excel* and the lines of data above this were then deleted in *Excel*. The remainder were selected and saved for analysis. The lines are one second apart as this is the GPS recording interval. The remaining lines are the track of the participant for *Phase 2* of the exercise,

the *Decision Making Phase*. This is then saved as the *Phase 2 track* for that participant. This is then also placed with all the other *Phase 2* tracks in a single file, the data for each participant separated from the next by a line with 'end' written on it. This indicates to other programs that 'end' separates participant's tracks. This data was used in the spatio-temporal analyses, including heatmaps, *Geotime 5.3* and fractal analysis.

7.5 Chapter summary

Conversation Theory with theories about learning from Cognitive Science lead to the idea that visualisations are cognitive artefacts that can be used as a pedagogy for delivering content about bushfires in CODE RED: MOBILE.

CODE RED: MOBILE with its various technologies and mobile access to the internet was presented as a *Mobile Learning System*. *7scenes* was shown to be a useful and practical means of delivering the *Mobile Learning System* framework as well as the game- like structure of the training exercise with rewards in the form of scores as well as the *gameplayer* (Cartwright 1999) metaphor and associated interactivity. The construction using *7scenes* of the game like aspects of the exercise were detailed and discussed. The method of cleaning the corrupted GPS tracks for Spatio-temporal analysis was outlined.

In chapter eight the preparations for the field trial are described and the development of materials for it. The experimental set up and recruitment of participants is outlined. Results of the experiment are analysed and answers to the research questions provided.

Chapter 8

The CODE RED: MOBILE experiment: outcomes and analysis

8 Chapter overview

The literature review in chapters one to four provided an account of research and information used to develop the prototype CODE RED: MOBILE as a tool or application for learning about bushfires on location. Key ideas from cognitive science, conversation theory, cognitive artefacts, pedagogy and knowledge about bushfires and mobile games led to the integration of the *Mobile Learning System* (Quinn and Cartwright 2009) about bushfires and wind changes with the game framework of *7scenes* on a mobile device- the *iPad 3*. This review provided a background to answering the principle research question which was:

Q.1 How can a conceptualisation of a bushfire, as visualisations in a game framework on a mobile device, best assist with the understanding of a virtual bushfire and enable decision-making about its behaviour in the real world location?

The CODE RED: MOBILE test bed was designed as a response to Q 1. The test bed sought to discover how best to train firefighters about the effects of a wind change on a bushfire. In chapter five the creation of the bushfire scene at Hanging Rock Reserve scene using *Sandbox2* was outlined. In chapter six a set of key concepts were found that were suitable for the game framework of the CODE RED: MOBILE test bed. Chapter seven described the creation of the details of this game framework in *7scenes* together with the set up of the

features that allow for the experiment that compares the learning materials treatments: dynamic-static and static visualisations. In addition methods used to correct errors before analysis of GPS tracks were outlined. This design phase of this prototype Live/Synthetic test bed, sought to answer three further research questions:

Q.2 Are dynamic-static visualisations superior to static visualisations for learning about a bushfire, in a mobile, Live/Synthetic, training exercise?'

Q.3 How can we record, visualise and analyse, participants' movements, in a mobile, Live/Synthetic, training exercise?

Q.4 Can fractal analysis of participants' GPS tracks assist the geospatial analysis, of Phase 2 of the exercise?

In the cycle of development of a project we proceed from formative to summative assessments and after each formative assessment improvements are made, in an iterative process of development. In this research each iterative stage of development was tested formatively but informally. There were many stages of development as the technologies changed and improved during the course of the research. There was the move from the *Unreal* games suite of editors to the *Crysis* suite, and then a major move from the *mscape* application (discontinued) on the *iPaq* (hp.com), to *7scenes* on *iPad 1*, then *iPad 3*. The experiment at the Hanging Rock Reserve, whose results are described later in this section, was a field trial of the *Sandbox2* visualisation editor's products, static or dynamic-static, in the game framework of *7scenes* on the *iPad 3*. Beyond that, an essential purpose of the research was to investigate the potential for computer game editors like *Sandbox2* to deliver information, on mobile devices, in a location based game-like exercise. Further, to discover what could be ascertained about the game or exercise design, from the scores on the tasks, that the firefighter participants had completed, as well as their GPS tracks.

At the end of the CODE RED: MOBILE exercise the *7scenes* application, by default, on the *iPad 3* asked each participant to review the application by making a comment or selecting a star rating out of five. This was not a required part of the exercise. The comments received and the star ratings are reproduced below:

- Longer briefing to give better picture of requirements. 4/5 stars.
- Felt I was playing golf and couldn't find my ball. 2/5 Stars.
- Good fun! 5/5 Stars.
- Good scenario got me thinking. 3/5 Stars.
- Very good. 4/5 Stars.
- Great training tool. Inaccuracies on track near northern edge of scenario. Hard to see/hear videos even with brightness/volume @ full. 4/5 Stars.
- Fire fighting 101. 4/5 Stars.

In general the participants were positive. One person wrote that the screen was hard to see and sound was difficult to hear. The participant who gave it 2/5 Stars had found it hard to locate places. These problems are important and should be considered in the design of mobile scenario based training exercises.

8.1 Embedding in the CFA and recruiting the participants

It was mentioned earlier that the author rejoined the Newham Rural Fire Brigade in 2008 with the idea of finding out how the Country Fire Authority (CFA) Brigades had changed their technologies and fire fighting practices since his membership in the 1970s to early 1980s. The local brigade was welcoming, needing people who could help with the financial and secretarial duties. Basic firefighter training had to be completed and this provided an insight into how firefighting had changed. Local Incident Control Centres had also been established since 2000 with teams of trained specialists for managing complex fires. Training as a fire mapper and fire behaviour analyst was undertaken. Being embedded in the CFA benefited the research as access

to the management level of the CFA was an opportunity to gain assistance for the recruitment of volunteer firefighters for a field trial of CODE RED:

MOBILE. In 2011 Mr M. Leitch, the CFA Mountain Group Training Manager was approached by a Mrs B. Kny, the training officer at Newham Brigade, who asked him if firefighters could be recruited for an experiment. The idea was presented to the committee and was unanimously supported. A range of dates was scheduled for the exercise at the end of 2011, however the fire season was anticipated to be bad for the 2011-2012 fire danger period due to low rainfall that spring and the exercise was cancelled. This however was an opportunity to improve CODE RED: MOBILE. In May 2012, the exercise was organised to take place over many weekends instead of just one or two. The Apple Australian University Consortium (AUC) had been kind enough to re-schedule the supply of 10 *iPad 3*, loaned for close to 4 weeks in May.

Mr M. Leitch contacted all the Brigade Training Officers for the CFA Mountain Group asking for volunteers to take part in the experiment. 33 firefighters responded. 10 firefighters could take part in the exercise at one time, the number limited by the number of *iPad3s*. The exercise was timed to be completed in less than 3 hours thus 2 exercises could be undertaken each day. Sunday is the normal training day for CFA Volunteer Brigades so generally this was going to be on Sunday though to accommodate one person, an exercise did take place on a Saturday.

8.1.1 Planning for the field sessions

The participant, to the bottom right on the far side of the lake, in Figure 7.1 at the beginning of the chapter, who took part in CODE RED: MOBILE in May, 2012; volunteered to give up a weekend morning, on what might have been a very wet, windy day in late Autumn. The week previous to the first exercise a trial version of CODE RED: MOBILE was carried out with family members, in cold, windy, and very wet conditions.

The weather was fine but cool for all the experimental sessions of the CODE RED: MOBILE exercise.

The design of the exercise had to consider that weather conditions might be far from optimal. Indeed participants were provided with ponchos. A4 plastic sheet protectors were used to cover the *iPad 3* screen. It was discovered that the touch screen still worked well under the thin plastic. The 10 *iPad 3* loaned by the Apple University Consortium (AUC) were insured by the University in case they were broken. RMIT University and the CFA were both insuring the participants. The exercise had to minimise the risk of injuries and equipment breakages. This was done by keeping the participants well away from the rocky, treed area that can be seen in the background of Figure 7.1. There are many snakes too, but the Macedon Ranges firefighters are generally used to their presence.

Participants in the morning sessions were provided with a barbeque lunch and drinks. Afternoon sessions were provisioned with snacks and drinks. ‘*An army marches on its stomach*’ attributed to Napoleon or Frederick the Great¹⁵ and certainly applies to CFA firefighters when on an exercise or tackling a fire. In addition, the food and drinks at the Hanging Rock South East Barbeque (BBQ) area, encouraged people to stay longer and discuss how the exercise went. This occasioned useful, but unrecorded feedback.

The participants were also issued with black recycled supermarket bags from Woolworths to carry the GPS device safely and also a map directing them where to go at certain stages of the exercise. The bag was also for carrying the *iPad 3* so that it was less likely to be damaged. The very smooth surface of the device meant that it slipped easily through the fingers. In addition they were shown how to use the bag if the sun was too bright to view the screen. This involved leaving the *iPad 3* in the bottom of the bag and putting their face inside close to the screen. However no one was seen using it in this way, they may have felt foolish. It was difficult to see the screen away from shade. Thus some of the design was about comfort and safety as it was an open air exercise. The ponchos in the bag seemed to give some of the participants the

¹⁵ The Oxford Dictionary of Proverbs (5 ed.), edited by John Simpson, Jennifer Speake.

feeling that they were being looked after. Several were surprised to find them in their bag. These basic considerations were necessary to help ensure that participants were more likely to enjoy and complete the exercise.

One needs to design and arrange an exercise like this with the participant in mind at all times. Their comfort, security and engagement are very important. *Engagement* was mentioned in Chapter 5 where McGonigal (2003 p.4) was quoted in relation to *Immersion* (a form of engagement) describing it as a ‘*virtual engagement with reality*’. Playing games (or scenario training exercises) where one must imagine the virtual, and relate it to reality, requires energy and commitment.

These basic considerations apart, the design and organisation of the exercise needed to be planned, and the *materiel* that accompanies it assembled.

The Hanging Rock Reserve was chosen as the venue for the scenario training exercise using CODE RED: MOBILE because it is within the Newham Fire Brigade’s and the Mountain Group’s area of operation. It is also very near the author’s residence. The terrain of Hanging Rock consists of the rocky remains of an upright lava tube, the rest of the volcano having long ago eroded away. This is a very rugged area unsuitable for an exercise. The rest of the reserve is flat, though with internal gated fences. It has a lake which is sometimes full of water but less so in midsummer and drought periods, a small river and the racecourse. These to some extent are obstacles but also provide boundaries and recognisable iconic features.

8.2 The Field Experiment for CODE RED: MOBILE

A quantitative approach to the statistical analysis was used. The inclusion criterion was that participants are over 18 and no other inclusion or exclusion criteria were incorporated. A sample of at least 20 participants divided into two groups was to be tested. However for some of the tests these numbers were not achieved for reasons detailed below.

The sample was from a large population of firefighters i.e. 15,000-20,000 CFA volunteers and it was determined that the small sample for CODE RED: MOBILE would not meet a test of normality. The non-parametric *Mann-Whitney U* test (Hole n.d.) was used as the data violated the assumption of normality meaning that a two-sample *t-test* could not be applied. The Mann Whitney test ranks scores from lowest to highest for each of the dependant variables and finds the mean of each. The α error probability of 0.05 was used and indicates that five out of a hundred times the analysis will falsely reject the null hypothesis.

8.2.1 The Participants

In total 33 firefighters attended, on the various days, with 30 actually undertaking the experiment. They were aged between 18 and 70+ and from local Mountain Group fire brigades. They were all qualified firefighters and had passed the basic firefighter course and many had further, more advanced firefighter qualifications. They took part in the exercise in groups over several weekends, except for one participant who came alone on 12th May, 2012, a Saturday morning.

Of the original thirty participants, five were eliminated from the experiment for reasons that are explained below. In addition, for unknown reasons, two participants had no recorded scores. Thus there were a total of twenty three participants whose scores on the tasks were recorded. Eleven were in Group 1 and twelve in Group 2.

Four of the twenty three were without recorded GPS tracks thus only nineteen had good GPS tracks. Eight were in Group 1 and eleven in Group 2.

All GPS were fully charged and held their charge throughout the day. Similarly the *Ipad 3* were fully charged each session and none developed a flat battery during the exercise.

8.2.2 Field sessions

On the first Sunday two sessions occurred, on subsequent weekends only one. The first Sunday 6th May, 2012 Mrs B. Kny, the Newham Brigade Training Officer, brought some of the firefighters from the Newham Brigade who had arrived for training that morning. Most had volunteered earlier but several new people also attended. A total of six took part. Two new arrivals declined to take part but walked around with a participant. They agreed not to discuss the exercise or any of the decision making or navigation. In the afternoon four participants came from other Brigades together with a further two from the Newham Brigade. At the end of this afternoon session two participants indicated that they were red colour blind and could not distinguish mauve/purple markers on the *iPad 3* screen from blue ones. One of these colour blind participants was later eliminated from the analysis, the other, unfortunately was included as he left before his name was ascertained. However if he looked at the other group's information for more than a few seconds, and this could be determined from the *7scene*'s website, then he was eliminated anyway. Participants were verbally informed in the briefing about the colours of the markers and where Group 1's and Group 2's markers were.

There was one person on the 12 May. The 13 May went much more smoothly and had eight participants. The 20 May had seven participants in the morning and three in the afternoon.

8.3 Analysis

8.3.1 Comparing the effects on Task Scores for Group 1 who received information as static visualisations and Group 2 who received dynamic-static visualisations.

In order to compare the effects on learning and decision making of the two treatments the research question asked:

Q.2 Are dynamic-static visualisations superior to static visualisations for learning about a bushfire, in a mobile, Live/Synthetic, training exercise?

This was tested by comparing two treatments for the delivery of the visualisations made in *Sandbox2*. The delivery of the media was as static media and as dynamic-static (Pfeiffer *et al.* 2009, 2011). The testing of the visualisations created in *Sandbox 2* whether static or dynamic-static was carried out during the scenario training exercise. This tested one aspect of the media delivered for learning about the behaviour of the bushfire. Maps were also supplied on location. These were not directly tested. Neither were many other features of the exercise. The *IBM SPSS Statistics 21* package was used for the statistical analysis. Group 1 saw static information in *Phase 1* and Group 2 saw dynamic-static. In *Phase 2* participants of both groups answered the House Task question on which of the 4 houses would burn down after the wind change. Only house 1 was likely to be burnt after the wind change. For each correct answer they received ten points. The *7scenes* application gave the participants another chance to get it correct. This could not be turned off in the free version of *7scenes*. There were only two choices thus this second chance should always be correct. *7scenes* gave the participant five points if they now responded correctly. This score of five was ignored in the analysis and only the first answer was accepted. There is a difficulty with this, in that, after seeing their answers were incorrect, participants were cued that the fire did, or did not impact the particular house they were considering. They may infer, which of the other houses were burnt, without considering the information delivered by the media. However, these cues may not have assisted someone who had not understood the media information about the location of the bushfire. Participants choosing randomly would on average get 50 % correct. These considerations lower the reliability of the results for this test. However, it was unavoidable without purchasing the full version of *7scenes*.

Participant's scores were observed in the window displaying the activity log for each participant on the *7scenes* website at www.7scenes.com. The raw scores were recorded for house 1-4 in a spreadsheet and summed and converted into a percentage. For the Debrief Task, undertaken after the exercise, participants were given a sheet with events in the bushfire in a randomly ordered list. They had to number each item in their correct order. This was scored with the following method, after a suggestion by Phira (2011) in answer to a question on the website:

<http://math.stackexchange.com/questions/40787/what-are-good-ways-to-score-an-ordering>: '*How many letters have to be removed to arrive at a correct ordering?*' Letters in this case meaning letters corresponding to event items but the score was the number of items then remaining in correct order. There were five items and each item in correct order received a point. The score was expressed as a percentage. The House Score and the Debrief Score were summed, expressed as a percentage and the result recorded as the Total Score.

The *Mann-Whitney U* test was used to determine if participants who received static visualisations (Group 1) tended to score lower than those with dynamic-static visualisations (Group 2) (the independent variables) in a decision making scenario in the field where firefighters chose which of 4 houses would burn after a wind change (the first dependent variable). The result of this test comparing the House Score between groups was not statistically significant, $z = -.446$, $p < .656$ as displayed in Table 8.1. The static treatment (Group1) had an average rank of 11.36, while dynamic-static (Group 2) had an average rank of 12.58 and is displayed in Table 8.2.

The Mann Whitney test ranks scores from lowest to highest for each of the dependant variables and finds the mean of each. The dependant variable with the highest mean rank has higher scores and participants in that group scored higher on that test. Thus Group 2 with the dynamic-static treatment had higher scores than Group 1 with the static treatment. The analysis reveals that this is not a significant difference. The result of the test

comparing Debrief Scores (the second dependant variable) between groups was not statistically significant, $z = -.318$, $p < .751$ as displayed in Table 8.5. The static group had an average rank of 12.41, while dynamic-static had an average rank of 11.63 as displayed in Table 8.6. In this case the static treatment has higher scores but not a significant amount.

This was also carried out for the Total Score (House and Debrief Score averaged and converted to a percentage, combining the two dependant variables). The result of this test comparing Total Score between groups was not statistically significant, $z = -.062$, $p < .950$ as displayed in Table 8.1. The static group had an average rank of 11.91, while dynamic-static had an average rank of 12.08 as displayed in Table 8.2.

	House Score	Debrief Score	Total Score
Mann-Whitney U	59.000	61.500	65.000
Wilcoxon W	125.000	139.500	131.000
Z	-.446	-.318	-.062
Asymp. Sig. (2-tailed)	.656	.751	.950
Exact Sig. [2*(1-tailed Sig.)]	.695 ^b	.786 ^b	.976 ^b

a. Grouping Variable: Group 1 or 2.

b. Not corrected for ties.

Table 8.1: The non-parametric *Mann-Whitney U* test of House, Debrief and Total Scores for Group 1 and Group 2. ^a.

The research hypothesis for this analysis was that static visualisations group (1) will have a lower score on the House Task in *Phase 2* than the dynamic-static visualisations' group (2). The null hypothesis was that each group will have the same distribution of scores on the House Task in *Phase 2*.

	Group	N	Mean Rank	Sum of Ranks
House Score	1	11	11.36	125.00
	2	12	12.58	151.00
	Total	23		
Debrief Score	1	11	12.41	136.50
	2	12	11.63	139.50
	Total	23		
Total Score	1	11	11.91	131.00
	2	12	12.08	145.00
	Total	23		

Table 8.2: *Mann-Whitney U* test for House, Debrief and Total Scores displaying rankings for Group 1 and Group 2.

The Asymp. Sig. (2-tailed) for *Phase 2* House Task scores is $p < .656$. Thus the null hypothesis must be accepted.

The research hypothesis for this analysis was that static visualisations group (1) will have a lower score on the Debrief Task in *Phase 2* than the dynamic-static visualisations' group (2). The null hypothesis was that the each group will have the same distribution of scores on the Debrief Task in *Phase 2*.

The Asymp. Sig. (2-tailed) for *Phase 2* Debrief Task scores is $p < .751$. Thus the null hypothesis must be accepted.

The research hypothesis for this analysis was that static visualisations group (1) will have a lower score on the Total Score in *Phase 2* than the dynamic-static visualisations' group (2). The null hypothesis was that the each group will have the same distribution of scores on the Total Score in *Phase 2*.

The Asymp. Sig. (2-tailed) for *Phase 2* Total Scores is $p < .950$. Thus the null hypothesis must be accepted.

Thus this experiment comparing the static and dynamic-static treatments of visualisations with the CODE RED: MOBILE location based bushfire scenario experiment indicates that there is no difference with this test between the two groups and the null hypothesis cannot be rejected. This is an indication that the use of static or dynamic-static visualisations does not affect participants' Task performance in CODE RED: MOBILE.

8.3.2 Group membership: Path Time and Path Length

In order to compare if there were other differences to decision making performance, in this case navigation decisions, as a result of the two treatments we can examine the distance gone and time taken in *Phase 2* of the exercise this also answers the research question:

Q.2 Are dynamic-static visualisations superior to static visualisations for learning about a bushfire, in a mobile, Live/Synthetic, training exercise?

Group membership i.e. media treatment was compared to the time taken or Path Time in *Phase 2* and the Path Length or distance travelled in *Phase 2*. The result of this test displayed in Table 8.3 comparing Path Time in *Phase 2* between groups was statistically significant, $z = -2.613$, $p < .009$. The static group displayed in Table 8.4 had an average rank of 13.20, while dynamic static had an average rank of 6.44. Group 1 had a mean time for *Phase 2* of 1338.8 seconds, group 2 had a mean time of 957.75 seconds. Thus Group 1 with static media spent a longer time completing *Phase 2* than Group 2 with dynamic-static.

The result of this test in Table 8.3 comparing Path Length in *Phase 2* between groups was statistically significant, $z = -2.410$, $p < .016$. The static group displayed in Table 8.4 had an average rank of 12.95, while dynamic-static had an average rank of 6.72. Group 1 had a mean path length of 1324.6 m. Group

2 had an average path length of 989.1 m. On average group 1 with static media walked much further than group 2 with dynamic-static media.

Table 8.7: The non-parametric *Mann-Whitney U* test of Participants' Time to complete *Phase 2* and the *Phase 2* Path Length for Group 1 and Group 2. ^a

	<i>Phase 2</i> Path Time	<i>Phase 2</i> Path Length
Mann-Whitney U	13.000	15.500
Wilcoxon W	58.000	60.500
Z	-2.613	-2.410
Asymp. Sig. (2-tailed)	.009	.016
Exact Sig. [2*(1-tailed Sig.)]	.008 ^b	.013 ^b

a. Grouping Variable: Group 1 or 2

b. Not corrected for ties.

Table 8.3: The non-parametric *Mann-Whitney U* test of Participants' Time to complete *Phase 2* and the *Phase 2* Path Length for Group 1 and Group 2. ^a

The research hypothesis for this analysis is that static visualisations group (1) will have a longer path and take more time in *Phase 2* than the static-dynamic visualisations' group (2). The null hypothesis is that the each group will have the same distribution of distance travelled and time taken in *Phase 2*.

The Asymp. Sig. (2-tailed) for *Phase 2* time taken is $p < .009$ and distance travelled is $p < .016$. Thus the null hypothesis can be dismissed.

Group 2, who saw the movies, walked on the whole significantly less distance and took significantly less time than Group 1. The distance covered and the times taken are aspects of the same phenomenon, in that it takes longer to go further.

	Group	N	Mean Rank	Sum of Ranks
<i>Phase 2 Path Length</i>	1	10	12.95	129.50
	2	9	6.72	60.50
	Total	19		
<i>Phase 2 Path Time</i>	1	10	13.20	132.00
	2	9	6.44	58.00
	Total	19		

Table 8.4: *Mann-Whitney U* test for *Phase 2 Path Length* and *Phase 2 Path Time* displaying rankings for Group 1 and Group 2.

However in CODE RED: MOBILE participants were expected to spend time getting close to the location of the House Markers and stand there and work out where the fire would be after the wind change and whether that would impact the particular house at which they were looking. The conscientious and the willing would perhaps take slightly longer time in proportion to the distance covered. Standing still does not increase distance, but it does increase time. On the other hand expert firefighters may not take too long to make their decision and not feel it necessary to get very close to the House Marker. Participants who have a very good mental model of the virtual fire and the landscape will possibly have made better navigation decisions on how to get to desired locations. They may well have remembered where fences and gates are and utilise those memories to choose a route that expends least energy whilst accomplishing goals. However then one would expect the high scores on the House and Debrief Tasks to show a difference for Group membership and they do not. Thus there must be some other factor that causes Group 2 (dynamic-static treatment) to walk faster and more efficiently, whereas Group 1 (static treatment) goes further and takes more time.

In summary the two treatments dynamic-static and static showed no difference for the House Task judging which house would burn and which would not, and on the Debrief Task sorting the order of events in the fire from memory. They did show a difference for length or distance travelled and time taken.

On balance the effects of Group 2 having a more game-like experience with an element of fun, together with the greater cognitive load of interpreting 3D animated dynamic visualisations inducing a more personal, allocentric cognitive model of the location and fire events, may have given them the advantage over Group 1. Group 2 with a shorter distance and time would have used less energy and therefore be more capable of fighting a real fire.

This is in accord with Fisher's (2010) findings that subjects learned less with animations but they were more engaged with them, creating an emotional response. And, Damasio (quoted in Milward Brown 2009 p.1) that emotion assists reason (Milward Brown 2009). Advertising about objects needs to include Knowledge, Experience and Emotion (ibid p.2). Established brands are best promoted with emotional advertising and for new brands informational advertising. The CODE RED: MOBILE exercise is designed for firefighters that are familiar with fire concepts, an emotional response is important to seize their interest as the 'product' is not new. This provides some justification for using dynamic-static media for mobile Live/Synthetic training exercises.

In the next section we look at ways of detecting which firefighters in the exercise were wandering more or less tortuously than others. This then is a focus on decision making about navigation and those who indicate '*interesting*' behaviours.

In the next section of this chapter we look at spatio-temporal techniques to assess if the GPS tracks of the participants in CODE RED: MOBILE display '*interesting*' behaviour of firefighter movements, which is to say behaviours that are unexpected yet actionable. Actionable in that in a real training

situation one might later be able to coach a particular participant to improve their performance. One might also use this type of knowledge to improve mobile location-based games and Live/Synthetic scenario-based training, for example by redesigning the layout of the game or training area so that participants do not take too long to complete the exercise nor walk too far to objectives. It may also indicate where, when and how participants' personal cognitive models or mental maps of events need to be improved to better enable efficient, allocentric navigation, and better decision making.

8.3.3 *Phase 2* GPS tracks

There were a total of ten participants in Group 1 with good GPS data, and nine in Group 2. First a look at how we can tease out information from participants' tracks for CODE RED: MOBILE. In Figure 8.9 the GPS tracks of the firefighters are in pink. The cricket wicket is a bright emerald green. Nearby the tracks form knots where errors in the GPS signal produce a range of locations as a participant stands still. The participants in *Phase 2* were much freer to make their own decisions on where to walk and in what order to do the House Task. Their decisions may be as much about ease of walking as of trying to complete the exercise quickly, either way the House Task markers had to be visited closely if they followed the instructions properly. Thus where the participants went was determined by the design of the game space in other words where the House markers were placed in relation to rivers, dams and pathways and the various patches of vegetation.

In this section the spatio-temporal analysis assists in answering the research question:

Q.3 How can we record, visualise and analyse, participants' movements, in a mobile, Live/Synthetic, training exercise?

This research question looked at participants' navigation decisions in *Phase 2* of the exercise in order to develop spatio-temporal game metrics that may inform the general analysis and design of mobile Live/Synthetic training.

Figure 8.1: GPS tracks on the Cricket Oval. The yellow knots near the bright green wicket, to the right or south east of the cricket club house, are where firefighters halted to read the *Task Marker* instructions.

The knots in the GPS tracks displayed in Figure 8.1 are places where people met and talked. The tracks are from all the sessions. General patterns are difficult to discern. A Kernel Density heatmap is displayed in Figure 8.2. It was made in *ArcMap 10* and displays the GPS tracks of participant

Figure 8.2: Kernel Density Heatmap in *ArcMap 10* displaying *Phase 2* of CODE RED: MOBILE.

firefighters in *Phase 2* of CODE RED: MOBILE. Again red areas show most activity and blue the least. The blue colour tends to indicate individual tracks, white a few more and red the most tracks in one place. This reveals where the majority of participants walked, the blobs of colour showing where many people halted at or carried out a close search for the 4 house markers. The large red blob to the bottom left shows where the BBQ shelter where the exercise started and finished. The hotter colours reveal where most participants walked and halted but they also reveal where individuals took a different route from the rest.

Figure 8.3: The *Phase 2* game area.

The three gates are choke points that participants had to pass through and show as red blobs.

Heatmaps provided an overview of what happened during the exercise. It reveals where the majority of people went and also where the least number of participants went. Both reveal information about the exercise and the participants. The scenario location (Figure 8.3) is paramount in importance to

a location based exercise; if the area is too difficult to navigate or negotiate it can have an impact on the results that can be achieved. The scenario exercise area at Hanging Rock is transected by a stream with several ponds or dams. In addition there are fences with gates to negotiate. The pattern in the heatmaps is driven by the navigation choices participants made. As the area to the south of the cricket pitch and racecourse is fenced and quite well treed; participants may come up with equally valid but completely different paths to get to the House Marker locations. The GPS tracks were imported through *ArcMap 10* to *Geotime 5.3*. *Geotime 5.3* can be used to find Active Zones where participants have been for certain lengths of time and within a certain distance of each other. This produces a form of heatmap that isolates the most active locations together with a list of the participants who were there. Figure 8.4 displays tracks for *Phase 1* and *Phase 2*. *Geotime 5.3* Active Zones has been set to find where 5 or more

Figure 8.4: *Geotime 5.3* displaying Active Zones for CODE RED: MOBILE. These are areas set in *Geotime 5.3* concerning how many participants spent set periods of time within set distances of a position.

participants have visited more than once within 50 m of the site and have been in the area for more than a minute. This captures the marker locations, although they are obscured in part by other traffic passing through. Locations marked with black numbers show the 11 areas found. Yellow indicates the amount of visitors. The black numbers 4, 1 and 2 were the markers for Group 2's *Information Phase*. Black 6, 5 and 11 (which however is conflated with a busy traffic junction, that included the Task Marker), are Group 1's *Information Phase* markers. Black 9, 8, 3 and 10 (conflated with the BBQ shelter) were the House Markers. Black 7 includes the gate and crossing over the racetrack that allows entry to the Cricket Oval area and the inside of the racecourse.

The original GPS tracks can be seen under the Active Zones. Lists of the participants who went through each area can be found. This revealed which participants did conform to the request for them to get close to the House markers and who took short cuts. It could also reveal participants who went out of the scenario area and were perhaps lost.

Figure 8.5: *Geotime 5.3* showing participants locations at the common start time for *Phase 2*. The two to the right are not in the correct location so there is an error needing correction.

Figure 8.5 shows participants at a common start time for Phase 2. Of course, in actuality they started at about 5 minute intervals in each session and there were several sessions. In the *Geotime 5.3* visualisation they start off in the animation in the order they are listed in the *Excel* spreadsheet. *Geotime 5.3* sets them off a few seconds apart. Most are in the area where the Task Marker was. This is the group to the left. The other two participants are in the wrong location off to the right and nowhere near the Task Marker. The track files for those two individuals had to be split again at the correct time. This resulted in all participants then being in the correct location for the beginning of *Phase 2*.

Movie screen captures can be made of *Geotime 5.3*. In Figure 8.6 a screen capture of that movie is shown. The icon representing a participant is shown on the black trace line of their GPS track.

Figure 8.6: 3 out of 17 participants in this visualisation did not go through the Active Zone marking the House three area which is coloured red. The dark pink coloured participants went through the Active Zone and went close to House three. The khaki (ID22), grey (ID10) and apricot (ID24) ones did not. They took a shorter more direct route.

The traces have been deselected. The GPS tracks have been overlaid on the heatmap of *Phase 2* movements. This partly overcomes the problem that heatmaps can obscure information. The icons are marked with the field exercise code for each participant and not the identity (id) number used later. The movie showed which participants did or did not go close to the House Markers. The Active Zone selected all those who went close to the House 3 Marker and they are coloured dark pink. The other 3: grey (ID 10), apricot coloured (ID 24) and khaki coloured (ID 22) did not go close. The apricot coloured one got quite close but did not go through the thick scrub to get closer. The transparent hole in the heatmap above the red Active Zone reveals the treed area which people went around. To the west or left there is another hole which shows trees and a lake or dam which was also avoided. To the east or right of the Active Zone another hole in the heatmap reveals a treed area that also contains a lake or dam. The pathways to the left or west of the Active Zone are gravelled. The paths to the east or right are mostly grassy. The heatmap, overlain by the GPS tracks, reveals high traffic as red areas. As the participants move into the treed area with a river and two dams participants take very different pathways. This is in the southern area south of the racetrack. Here the concentrations of movement are near the houses and the BBQ area that is the start and finish. This dissipation of people in the forested area may not be desirable as the exercise needed to be completed quickly and without the participants getting too tired. Mobile scenario training exercise can benefit from using spatio-temporal analysis with heatmaps of all the GPS tracks, overlaid with the actual tracks of the individuals. A redesign of the exercise could make it less stress and easier by providing directions through these confusing areas.

The three participants: May13 crm 5 khaki coloured, ID 22, apricot coloured crm1, ID 24 and grey coloured crm4, ID 10 did not go to the House markers. In Figure 8.11 the grey coloured icon appears to be crm1 but this is an artefact of the screen capture. The grey icon is in fact crm 4, ID 10. In addition crm 6, ID 2 and crm 3, ID 15 move along a very similar track. They

were in the same session on the morning of 6 May, 2012. Similarly ID 3 and ID 4 walked similar paths, though with minor variations and were in the same session on the morning of May 13, 2012. These two pairs must have caught up with each other and walked together in *Phase 2*.

8.4 On Fractal D, Spatial Scale

A fractal analysis of participant's tracks provides insights into the exercise space and layout. This assists in answering the research question:

Q. 4 Can Fractal analysis of participants' GPS tracks assist in the analysis and description of the geography of Phase 2 of the exercise?

Figure 8.7: Near identical GPS tracks for ID 15 above and ID 2 below.

Figure 8.7 shows the GPS tracks for *Phase 2*, and they are very similar for ID 15 and ID 2. Fractal shapes have same pattern at all scales or magnifications (Mandelbrot 1982). A fractal dimension of 1 is a straight line and 2 is so tortuous that a plane is covered completely.

Figure 8.8: Fractal D: Spatial Scales 1-250, divisions 50. ID 15 above, ID 2 below.

In Figure 8.8 the *Fractal* application, version 5.20.0, 2010, authored by V.O. Nams (1996) has been used to find the Fractal D score at spatial scales from 1 to 250 m. The *Fractal* application was set to 50 divisions which produced a more detailed graph. The graphs are nearly but not quite identical. Figure 8.8 will be referred to again in the next section which deals with fractals, what they are, and what they can reveal about participants' performance in mobile scenario training exercises, and how that may assist in analysing and improving the exercise itself.

The context of *Phase 2* at Hanging Rock is shown in Figure 8.9. The area of the heatmap overlay occupies a virtual rectangle approximately 530m by 600m. This is the 'play' or exercise area of *Phase 2*. The GPS tracks were all within this rectangle in *Phase 2*. Gate 1 and Gate 2 allow passage between the racecourse area and the area to the south, called here the southern BBQ area. Participants had to choose which gate they would use.

Figure 8.9: Features of the *Phase 2* area. Dimensions of Heatmap overlay are 530 by 600m.

The southern area also contains the finish and start of the exercise at the BBQ shelter marked on Figure 8.9. After leaving the BBQ shelter at the start of *Phase 1* participants entered the racecourse through the east gate, Gate 1. In *Phase 2* some participants being familiar with Gate 1 went through it to get to the southern area and the finish at the end of *Phase 2*. Other participants went through Gate 2 to the southern area. If one intended to visit all the Houses then going through Gate 2 was quicker than going through Gate 1. Using the heatmap it can be seen that most used Gate 2. Participants who went through Gate 1 tended not to visit House 3 and 4 closely.

Dam 1 and Dam 2 as well as the gates and fences constrained how far one could go in a straight line. They also affect the tortuosity or Fractal D of the path taken. Routes round, through or over obstacles that must be taken will also increase the tortuosity of participants' paths.

The heatmap, which is overlaid onto the base map, in Figure 8.9, displays a wide variation in choice of route, although the 'hotter' red areas show that

there was some consensus in *Phase 2* amongst the participants. The consensus is greatest in the open grassy areas and least in the bush area to the south of the racetrack.

8.4.1 Domains of Spatial Scale for the prototype CODE RED: MOBILE exercise.

Spatio-temporal tools, heatmaps and fractal analysis provide methods for analysing participants' movements in the *Phase 2* area of the CODE RED: MOBILE exercise. Fractal D at a range of spatial scales can find transitions and thus Domains for the CODE RED: MOBILE exercise. This then provides a description of *Phase 2* of the exercise and thus an analysis tool for the design of the game phase.

Figure 8.10a displays, at spatial scales of 10-250m, the mean of the 19 GPS tracks for *Phase 2* of CODE RED: MOBILE. The log of distance is plotted against spatial scale. The 5 domains match the domains found in Figure 8.10b where Fractal D is plotted against spatial scale. These changes at

Figure 8.10a: Log of Distance against spatial scale reveals 5 Domains. Plateau and trough refer respectively to the Domain 3 and 4 features in Figure 8.31b.

the boundaries between the domains reveal patches that differ from one another in vegetation, roughness or impenetrability of the terrain or the tortuosity of their formed paths.

Figure 8.10b: 10-250m spatial scale of all 19 GPS tracks for *Phase 2*. There are 100 divisions (marked by bold dots) along the middle line which is the mean Fractal D line. The lines either side are the Confidence Intervals at 95%. Fractal D = 1.1833, standard error (se) of Fractal D = 0.0128, 95% confidence interval (c.i.) Fractal D = 1.1566- 1.2100

These changes between domains are transition zones which reveal that the participants' tracks are scale variant and a statistical fractal (Doerr and Doerr 2004). These changes show that the firefighters navigation behaviours, whether more or less tortuous, are responding to features in the landscape. It may be easy to find ones way or it is difficult, perhaps because the vegetation is dense, or a fence or river bars the way.

In Figure 8.10b the Confidence Interval gets wider from Domain 1 to Domain 2, much wider in Domain 3, a little wider again in Domain 4 and much wider in Domain 5. This shows that variability in the tortuosity of the tracks of participants increased from Domain 1 to Domain 5. The Fractal program (Nams 2010) did not chart beyond approximately 200m as in Figure 8.10b although it did for the Figure 8.10a chart where distance is plotted against spatial scale. The Confidence Interval for Domain 5 in Figure 8.25b is wide. The Fractal D for all 19 participants for Spatial Scales 170-250m is Fractal D = 1.8414, standard error (s.e.) of Fractal D = 0.1580, 95% confidence interval (c.i.) Fractal D = 1.5094- 2.1733.

There is a big jump in variability between the first two domains and the following three domains. In the second three domains the participants are much more variable in the tortuosity of their tracks. This suggests that in

Domain 1 and 2 participants find navigation straightforward. Domains 3, 4 and 5 are at increasingly larger scales of movement that require more orientating and planning. At these spatial scales in Domain 3, 4 and 5 participants may have to explore and use hit and miss tactics. The *7scenes* application with a participant's location indicated with a blue sphere overlaid on the *Google* satellite image should have scaffolded the navigation experience to some extent, as much of the cognitive load of navigation was offloaded to the *iPad 3*. Knowing where you are is only half of the equation as planning a route cannot be offloaded to *7scenes*. The map was fixed so that north was at the top of the screen, thus participants also had to orient the *iPad 3* if they wanted to their track on the screen to match their walking direction. The mental rotation of the direction of travel on the device to the real direction of travel is sometimes difficult to do, and personal skill levels may affect the tortuosity of tracks, and thus the Fractal D at various spatial scales.

Much of the Fractal D variation at the various spatial scales is accounted for by the nature of the *Phase2* area at Hanging Rock. Participant's tracks at Spatial Scales 10-30m in Domain 1 tend to be straight; these may be formed paths in the reserve, or natural paths in the terrain (Table 8.5).

Domain	Spatial Scales	Average Fractal D for 19 participants	Description
1	10-30m	1.0973	Straight footpaths at a small scale
2	30-83m	1.1741	Smaller open areas or footpaths at this length
3	83-140m	1.3700	Large scale internal obstacles like fences or water obstacles with hard to find gateways and bridges
4	140-170m	0.9747	Very large scale open ground or long straight footpaths (interrupted?)
5	170-250m	1.8414	Very large scale external barriers, obstacles and features, causing hair pin changes of direction and re-crossing of tracks.

Table 8.5: Spatial Scales of 1-5 Domains, Fractal D and description of the nature of the game layout.

Domain 2 at Spatial Scales 30-83m; tracks are a little more tortuous. Domain 3 at Spatial Scales 83-140m shows more intensive searching behaviour in what might also be called a patch which is '*interesting*'; at this quite high level of tortuosity participants are looking for ways through and around large obstacles like fences and dense vegetation. Domain 4 is a return to the straighter paths as for Domain 1 and 2 except the lengths are much longer from 140- 170m, thus there is a return to easier and probably quicker journeys over open ground or along long more or less straight paths. Domain 5 at Spatial Scales 170-250m involves very large scale tortuous paths where very large scale boundaries cannot be easily broached and must be turned away from. They feature tight turns or require long walks around. This level of '*interesting*' is likely demanding on participant's decision making and navigation; mistakes or errors of judgement may lead to long frustrating walks in the wrong direction at a large scale.

This range of navigation behaviours is analogous to the three domains of spatial scale for the Wandering Albatross (Fritz *et al.* 2003). The transition zones for CODE RED: MOBILE participants in Figure 8.10b are corollaries of the albatross transition zones in Figure 4.17. Domain 1 for the Wandering Albatross features the zig zag soaring flight at a small scale, but overall a straight path out to the feeding areas. Domain 2 flight patterns is that of a bird looking for food and flying in straighter lines and turning at a scale of kilometres to stay in the food bearing area, and Domain 3 where the bird is turning gradually at scales of a hundred kilometres in a global path that takes it back to its nesting island.

For CODE RED: MOBILE; Domain 1,2 and 4 are open areas where distance is covered in relatively straight lines; and for Domain 3 and 5 participants are turning away from external barriers at the larger scales of Domain 5, and getting through gaps and passing over bridges to broach internal barriers at the scales of Domain 3.

Figure 8.11: Fractal D chart for *Phase 2* of ID 6

Figure 8.11 allows us a view of the Fractal D at spatial scales 10-250m for ID 6, a participant in CODE RED: MOBILE whose chart resembles the chart for all 19 participants displayed in Figure 8.10b. ID 6 had a Fractal D of 1.3578 for *Phase 2*. Although ID 6 visited 3 Houses closely, House 1 was not visited very closely. Participant ID 3 (blue) with a Fractal D of 1.5128 and participant ID 4 (black) with a Fractal D of 1.5123 appear to closely follow the hotter red coloured areas of the heatmap. Both have a much more tortuous average track than ID 6 perhaps because they were more exact about visiting the locations of the House markers.

Figure 8.12: Track for ID 6 (yellow)

The track of ID 6 (yellow) in Figure 8.12 does not follow the red of the heatmap to a large extent but the fractal domains are similar to that shown in Figure 8.10b which is the average track for all 19 participants.

In the CODE RED: MOBILE exercise *Phase 1* had a restricted area where pathways for the participants were close to mandated, whereas *Phase 2* had a freer choice of pathway. However the *Phase 2* area was divided in two by the fence around the racetrack which has only two gates through it. Refer to Figure 8.9 to see the location of the gates.

ID 13 scored 100% on the Task and Total Score and had a path length of 1506 m and a time of 1495 seconds for *Phase 2*. ID 13 Fractal D was 1.4848. ID3 path length was 1233 m, and path time 1008 seconds and a Fractal D of 1.5128 and ID4 had a path length of 1215 m and a path time of 974 seconds and a Fractal D of 1.5123. They both had a 100% Total Score. ID 3 and ID 4 were accurate and walked *Phase 2* in less distance and in less time than ID 13. Figure 8.13 displays ID 3, 4 and 13's GPS track. ID 3 and ID 4's track are

very similar. They were present in the same session and probably walked together for most of *Phase 2*. They outperformed ID 13 by covering less ground in less time but walked a more tortuous route on average. This may show that ID 3 and ID 4 worked harder at getting close to the House marker locations and were efficiently navigating their way from one House marker to another.

Figure 8.13: ID 3 (blue) and 4's (black) track are very similar. ID 13 (pink).

8.5 Chapter summary

This chapter analysed aspects of participant's performance in the CODE RED: MOBILE exercise at the Hanging Rock Reserve. Participants had to judge which of four houses would burn down after a wind change had affected a bushfire at Hanging Rock Reserve. They were provided with learning media created in the *Sandbox2* editor provided with the *Crysis Wars* computer Game (crytek.com) as well as maps and textual information. There was also an examination of participant's navigation during *Phase 2* of the exercise. This used heatmaps and Fractal D scores of the GPS tracks. This information

assisted in developing the division of the exercise event and space into five spatial scale based Domains. This is not a division into five regions, but rather five types of movement related to the nature of the game landscape at various spatial scales of movement.

Static and dynamic-static treatments of visualisations produced no difference on participants' performance on the House and Debrief Task or to the Total score in CODE RED: MOBILE. However Group 2 (dynamic-static treatment) walked less far in *Phase 2* and took less time than Group 1 (static treatment) who went farther and took more time. Thus the treatments appear to have had a statistically significant effect on navigation with Group 2 taking less time and walking in less tortuous tracks than Group 1. The dynamic visualisations perhaps provided no advantage to solving the problem of which houses would burn down because the House Task was very easy for trained firefighters. On the other hand the navigation task was difficult and perhaps the dynamic-static visualisations assisted.

There was no statistical significance with those who scored above or equal to 75% on the House Task, or for those who scored below 75% on the House Task and the media treatment they received.

Participants, that scored 75% or over on the House Task also scored higher on the Debrief Task. They also walked further and took longer to complete CODE RED: MOBILE than those who got less than 75%. The participants who achieved 75% or over were perhaps more diligent in visiting all the House markers as asked and spent more time and walked further in doing so.

It appears that the visualisation type received had little effect on the House, Debrief and Total scores but participants who scored over 75% on the House Task walked further and took longer to complete the *Phase 2* part of the exercise.

Seven out eight of Group 2 scored equal to or greater than 75% on the Total Score. Seven out of eleven of Group 1 scored equal to or greater than 75% on

the Total Score. Overall fourteen out of nineteen or 73.7% scored equal to or greater than 75% on the Total Score. The mean score for all was 78.9%. This is a very good outcome for the pilot exercise as it was its first run, with participants unfamiliar with mobile training using *7scenes*, and the *iPad3*.

When assessing a layout for an exercise or game it may be useful to carry out trials like the prototype CODE RED: MOBILE Live/Synthetic exercise and examine changes in Fractal D and thus navigation behaviour at various spatial scales. Determining the domains of spatial scales of the game or exercise area reveals how participants' performance is affected by the landscape, its scale and accessibility as well as the design of the exercise. This can then assist in developing improved versions of location based mobile games or training scenarios.

The final chapter addresses the research presented here and determines to what extent it has been successful. The research questions are examined with reference to the objectives, findings and outcomes of the prototype CODE RED: MOBILE Live/Synthetic exercise and the tools that assisted its creation. The limitations of the research are outlined together with some suggestions for further research.

Chapter 9

Conclusion

9 Chapter overview

The CODE RED: MOBILE test bed, features a Live/Synthetic mobile training game for firefighters, enhancing learning and decision making about a virtual bushfire by delivering visualisations and other media at the fire's real world location.

The thesis statement, above, encapsulates the CODE RED: MOBILE test bed, and the exercise it enabled. The test bed was used for several experiments: one which compared two treatments of the media about the bushfires; and another, where participants' GPS tracks underwent spatio-temporal analysis.

In the State of Victoria bushfire disasters have had a long history. Community response to fires at first borne by individuals; quickly became a government responsibility. The CFA of Victoria being established in 1944 by Victorian Government Act. The CFA instituted an infrastructure for training in 1946. In more recent times the Black Saturday fire (2009) struck, and subsequent inquiries found deficiencies with the emergency services. The introduction of the 'Minimum Skills' prerequisite for firefighters after the Linton Fire of 1998 (Cheney *et al.* 2001) and the 'Skills Maintenance Drills' in 2012/2013 has rationalised and systematised the training framework for the CFA in Victoria.

There is no mention of mobile training in documentation relating to 'Minimum Skills' or in the 'Skills Maintenance Drills' despite the burgeoning use of mobile devices in the CFA and other emergency services. In addition there is no explicit exercise about a bushfire undergoing a wind change in the 'Skills Maintenance Drills' despite the disastrous effects of a wind change on

the Linton Fire and the 1983 Ash Wednesday and the 2009 Black Saturday fires. The CODE RED: MOBILE test bed was a demonstration that mobile training about bushfires undergoing a wind change is a viable and useful method of filling the current gap in training. This project in its examination and exploitation of the concept of mobile Live/Synthetic training is proposed as a way forward for organisations like the DEPI and the CFA.

9.1 Empirical findings

Q.1 How can a conceptualisation of a bushfire, as visualisations in a game framework on a mobile device, best assist with the understanding of a virtual bushfire and enable decision-making about its behaviour in the real world location?

The conceptualisation, mental model, or cognitive map of a bushfire, termed the *Bush/Grass Fire Disaster Schema* in Figure 7.3 was used to make geovisualisations in the form of an animated movie or a screenshot from that movie, annotated appropriately. A set of these geovisualisations was delivered in the game framework provided by *7scenes*. The key part of the question is how the conceptualisation **best** can assist in learning about the virtual fire. The literature review and its examination of a wide range of fields of study led to the development of three further research questions.

Q.2 Are dynamic-static visualisations superior to static visualisations for learning about a bushfire, in a mobile, Live/Synthetic, training exercise?

Q.3 How can we record, visualise and analyse participants' movements, in a mobile, Live/Synthetic, training exercise?

Q.4 Can fractal analysis of participants' GPS tracks assist the geospatial analysis, of Phase 2 of the CODE RED: MOBILE exercise?

9.1.1 Responding to the research questions

The research proposed that off the shelf computer game editors and a free version of the mobile game framework *7scenes*, could be used to develop a proof-of-concept prototype mobile exercise for learning about the dangers of wind changes on bushfires. This was developed by employing several fields of theoretical knowledge, which provided design principles for learning about bushfires, visualisations, game and mobile aspects of the exercise. The research questions and the thesis statement assisted in developing CODE RED: MOBILE, guided the scope of the literature review and subsequently the development of the experimental design.

The literature review presented the development of the *Mobile Learning System* concept (Quinn and Cartwright 2009). This guided the design and construction of the mobile location and scenario based exercise prototype. Chapter 3 examined the design of media especially animations. Animated movies are problematic for learning, researchers differ on whether they enable or inhibit learning, although there is a developing consensus that a mix of annotated static screenshots and illustrations within an animated movie leads to better results for learning whilst gaining motivation and attention with the dramatic impact of the animation .

The developed media in the prototype mobile exercise provided an opportunity to deploy an experiment that would compare the dynamic-static movies and static images of the geovisualisations of the bushfire. This experiment was the subject of Question 2.

Q.2 Are dynamic-static visualisations superior to static visualisations for learning about a bushfire, in a mobile, Live/Synthetic, training exercise?

The experiment compared static and dynamic-static treatments of visualisations using the CODE RED: MOBILE test bed. It returned the result that the null hypothesis cannot be rejected because there was no significant

difference between the two groups that had received the two treatments of the visualisations. The static (Group 1) and dynamic-static (Group 2) treatments of visualisations showed no differences on participants' task performance.

On the other hand Group 2 (who saw dynamic-static movies) walked on the whole significantly less distance and took significantly less time than Group 1 during *Phase 2* of the exercise. The distance covered and the times taken are, to some extent, aspects of the same phenomenon, in that it takes longer to go further. It may be that Group 2 had developed a better mental model of the landscape or that the movies had motivated them more than Group 1 to be conscientious and do well. It may be that Group 2 was simply better at navigation, by chance.

Q.3 How can we record, visualise and analyse participants' movements, in a mobile, Live/Synthetic, training exercise?

This question was addressed by the literature review in particular Chapter 4 'Learning where we are' and Chapter 5 'Playing games seriously'. The CODE RED: MOBILE package of tools included recording GPS tracks of participants. The finding of five Domains of spatial scales revealed participants' navigational responses to the layout of *Phase 2* of the exercise. These decisions were affected to some degree by the physical layout of the exercise area and the task marker locations. The heatmaps of *Phase 2* were a visualisation of where participants had walked, and in combination with the *Geotime 5.3* space-time analysis lead to some inferences about where participants took shortcuts and who did not adhere to rules.

Q.4 Can fractal analysis of participants' GPS tracks assist the geospatial analysis, of Phase 2 of the exercise?

Spatio-temporal visualisations are a powerful means of observing individual and whole group average behaviours. The Heatmaps reveal where the most frequent paths were, as well as where stopping or slowing down behaviours

occurred, such as where a narrow gap like a gateway or bridge meant participants had to go through. The Fractal D findings provided further breadth to the spatio-temporal analysis for the individual and the average of all participants.

The finding of five Domains of spatial scales using Fractal D indicated that a mobile training exercise or indeed a location based game can be broken down into domains that reveal participants responses to the character of the game area, such as the terrain and layout of obstacles and ways through or around barriers of thick vegetation or water. Thus the classification of a set of GPS tracks into five Domains provides a means of clarifying at which spatial scales participants are searching for things like markers, gates and bridges, where they are travelling easily, and where they have to suddenly turn back from boundaries.

For CODE RED: MOBILE; Domain 1,2 and 4 are open areas where distance is covered in relatively straight lines; and for Domain 3 and 5 participants are turning away from external barriers at the larger scales of Domain 5, and getting through gaps and passing over bridges to broach internal barriers at the scales of Domain 3.

The question then is how to balance the game or exercise so that easy and difficult sections are in the right proportions to create a good experience of learning with some difficulty but not too much. Analysing the Domains of an exercise or game may assist in balancing easy and difficult sections of mobile location based games and mobile scenario based training exercises. Fractal analysis of GPS tracks provides a useful tool for analysing the design of mobile location based exercises and games. This can also be used to improve the design of the layout of the exercise.

9.2 Future directions

Dynamic-static and static visualisations may be used in a mobile training exercise. They produced similar learning and decision making in CODE RED: MOBILE. Both were used in CODE RD: MOBILE and were derived from a movie made in a 3D game editor. This media is expensive to produce commercially and organisations that could not afford it would have to consider alternatives.

The pilot exercise participants scored reasonably well with fourteen out of nineteen or 73.7% scoring equal to or greater than 75%, and a mean score for all of 78.9% on the Total Score, which combined the House Task score with the Debrief score. This outcome for the pilot exercise with firefighters unfamiliar with the game framework application on the mobile device showed that mobile Live/Synthetic training exercises are feasible. Scenarios can be developed for a fire station's local conditions, although most would not use a game engine editor for animated movies and static images, as maps and drawings will work fine. In the next section a way forward is presented.

Live/Synthetic training exercises are being actively pursued mostly by the US military and its allies. The mix of live participants in real aircraft with virtual targets, and the rival forces controlled tactically and strategically from the constructive environment, makes for an interesting mix. The real forces can train more often as the exercise is less costly.

The ideas of Live/Synthetic training that include virtual and constructive elements are a way forward for prototype test beds like CODE RED: MOBILE. Of course the research effort afforded by the US military and its allies cannot be replicated in a small project like CODE RED: MOBILE. However applications like *eMap*, currently used by DEPI and the CFA in Victoria, could be adapted as the constructive element. *eMap* links through digital radios, with in-built GPS, to track ground and air, vehicle movements. In a Live/Synthetic exercise vehicles and aircraft, created virtually and controlled by pilots or the training supervisor, could be followed in the

constructive *eMap* context. However the track view has a time lag, which would affect decision making.

In an Incident Control Centre exercise, a game engine generated 3D view of a fire could provide context for training exercises. Firefighters operating virtually in a game based fire would be integrated into the constructive view. This kind of training would be suitable for personnel in Incident Control Centre roles. Using vehicle and aircraft tracking preserved during bushfire response, incidents could be ‘refought’ using *eMap* or a derivative. *eMap*, adapted for ‘virtual injects’ as the basis of the constructive view for a Live/Synthetic exercise would also enable large scale exercises involving remote fire brigades and fire fighters.

Trialling the CODE RED: MOBILE test bed with other emergencies such as floods and perhaps crowd control for sporting, entertainment or politically inspired events would also be a suitable extension of the current project. The Rolling Stones concert which will be held in late 2014 expects something like 17,000 patrons. The venue at Hanging Rock establishes its own ICC for such events, but there is no exercise beforehand as to what could go wrong and what suitable responses are. A training exercise could utilise movies from the author’s 3D model of Hanging Rock, and the CODE RED: MOBILE Live/Synthetic test bed could be adapted for the concert. The *eMap* application could be used as the constructive environment if a method of allowing injects was created.

In addition, it is suggested here that the prototype CODE RED: MOBILE would complement the *BF003 Bushfire Safety and Survival* unit. In addition many of the ‘Skills Maintenance Drills’ in Table 6.1 could be complemented with mobile device based practical sessions of training.

9.3 Limitations of the research and recommendations

The results of the research were presented and analysed in Chapter 8 and were the product of data collected from an evaluation with over 30 firefighters over several sessions in May 2012 at Hanging Rock. Findings were presented and discussed and point towards the special affordances of mobile learning using movies created with game engine editors, together with some novel analyses of navigation in the exercise. However there were some stumbling blocks and deficiencies in the research.

The findings of this research have deficits and limitations and from this some recommendations for future research may be offered. The static and dynamic-static visualisation information was backed up by maps showing where the fire had progressed at the various stages of the fire. It was thought that there ought to be the same type of information available to the firefighters as at a real fire or a training fire where maps are generally available. The Spatial Vision mapbook is carried on all CFA fire vehicles although of course the fire outline is not mapped. It may be that there was enough information on the maps for many of the participants to solve the decision making tasks without using the static and dynamic-static visualisations. This may have confounded the results to some extent. It would be interesting to run the experiment with no fire progress maps.

There were other difficulties in the exercise. The *ipad 3* has a screen which is not very visible in bright sunlight. Also the Task questions in *7scenes* gave a second chance to participants who had got the answer wrong. Thus they were told in a sense where the fire was, and was not. They then, by inference, could work out which of the other houses would burn down after the wind change altered the direction the bushfire travelled. However, as the participants were trained operational firefighters, and very likely to have worked out where the fire had burnt already, it was thought that few of them would use the information received from the second chance on the question at the four House markers. The exercise itself, being so simple, the comparison between

the media treatments is perhaps not a very stringent means of testing differences in learning and decision making between the two treatments of the information media. The test did ensure that the participants had a reason to be at the 4 markers in order to trial the GPS tracking.

The trial of the proof-of-concept prototype concentrated on the learning and navigation of the participants in the exercise but did not compare the exercise to a desktop version of the exercise or indeed the static and dynamic-static media to a paper based table top exercise.

There could have been a comparison carried out between the proof-of-concept prototype and an exercise that occurred in a flat area away from the iconic features of Hanging Rock. If the results for each were similar then this would show that the exercise could be carried out in any large field and thus could be transposed to any location. Another comparison exercise could also be at a much smaller scale than reality. This could incorporate models of Hanging Rock and some of the reserve's other features including model houses laid out in their correct relative locations. This could establish if learning about the effects of a wind change on a bushfire can be satisfactorily carried out in a school ground or a CFA Fire Station's forecourt using the scenario and visualisations from Hanging Rock.

Recruit firefighters with no experience of fires could have been compared to experienced firefighters. This would have been an interesting test of how well the 'Minimum Skills' training fresh in the minds of the recruits fared against firefighters with experience of fighting actual fires.

In 2012 the CFA 'Skills Maintenance Drills' were introduced but by mid 2013 were only beginning to be used at the Newham Fire Station. An experiment comparing firefighters who have completed and those who have not undergone (Fig 6.24) the *BF003 Bushfire Safety and Survival* training session using the proof-of-concept prototype CODE RED: MOBILE experiment would probably not be valid as *BF003 Bushfire Safety and Survival* does not explicitly involve a bushfire undergoing a wind change.

The exercise for all its difficulties went very well, assisted ably by some volunteers and the good natured participation of the experimental subjects. It provided a successful trial with some interesting results that can be the basis for future research work in this field.

9.4 Chapter conclusion

The CODE RED: MOBILE test bed, features a Live/Synthetic mobile training game for firefighters, and proved its value in the field trial to simply and interestingly deliver a training exercise on location.

The experiment comparing dynamic-static and static media for learning and decision making carried out with the CODE RED: MOBILE test bed was inconclusive, as with many experiments comparing learning methods. In other words either media type is effective, at least in terms of learning about a bushfire, and answering some decision making questions, and in remembering events of the exercise in a debrief activity.

The GPS tracks proved a rich source of data for analysis. Heatmaps and Geotime 5.3 visualised the movements of the firefighters in *Phase 2*. This provided a means of understanding the movements of the participants.

The GPS tracks were used with fractal analysis to determine that participants on average were behaving differently in each of five Domains of the *Phase 2* game area. For three of the Domains at different spatial scales, participants were walking freely through open areas, in another Domain they were looking for gaps or ways through internal barriers and at the largest scale Domain they were meeting external barriers and turning back in hair pin bends or recrossing their tracks.

It is interesting that firefighters in Group 2, who saw the movies, walked a shorter distance in less time, but with a more tortuous path, than Group 1 who saw only static media. It suggests an inference that:

Group 2 were emotionally affected by the game-like excitement of the movies, and this caused them to have greater motivation, 'flow', and 'engagement' in the exercise, so that they paid more attention to navigation, and better used clues on the device, and the landscape. Their more tortuous path shows they were more dedicated in getting close to the House task markers, than Group 1.

This shows that Live/Synthetic exercises, containing dynamic-static movies may have effects not so much on abstract learning, but more on motivation and physical and emotional response to this kind of training.

In the management of a critical incident there are personal, emotional, legal and fiscal implication, and consequences. When you have thirty minutes to rough out a fire prediction, and people are looking over your shoulder; it is training under controlled pressure that counts, as much as the intellectual calculations involved. Firefighters who continually train in dull, colourless, undramatic exercises will not have the same resilience as in Live/Synthetic exercises with dramatic movies, which bring a frisson of fear and life to a simulated incident. They may not learn better, but perhaps, they will perform better, and save more lives.

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Appendix

Application for Review by the College Human Ethics Advisory Network (CHEAN) of Negligible / Low Risk Research.

Application for Review by the College Human Ethics Advisory Network (CHEAN) of Negligible / Low Risk Research¹⁶

About this form:

This application form should be used by researchers seeking ethics approval from the CHEAN for human research projects that have been assessed by the RMIT HREC “Checklist for negligible and low risk research” as presenting no more than low risk to research participants (i.e. risk that is no more than discomfort).

The completed checklist must be attached as a cover to this form

Attachments:

You need to include with this application the following supplementary documents (where applicable)

- A completed checklist (either negligible risk or low risk checklist as appropriate)
- Participant Information sheet/plain language statement
- Informed consent form distributed to participants
- Questionnaires or any survey instruments¹⁷
- Any other documents (for example, approvals from other organisations to conduct research) or other documents required for the research project

Submitting the application form:

Submit your **original** and **signed** application form as well as any supplementary information to your relevant CHEAN secretary. Please go to your college website to ascertain where to send your documents and how many copies you will be required to submit. All initial correspondence about your application should go through the CHEAN secretary.

You must not commence data collection until you receive written approval from the CHEAN

¹⁶ Adapted from Queensland Government, Queensland Health “Application for review (HREC or Non-HREC) of low risk research” 2008

¹⁷ It is recognised that there are some questionnaires or survey instruments that can’t be attached because of their size and type. In that case, you must provide a full description and citation

Application for Review by the CHEAN of Negligible / Low Risk Research¹⁸

Application Number (office use)		Approval Date (office use)	
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1 PROJECT TITLE	Investigating the design of visualisations made with COTS game for learning about bushfires in a mobile scenario.
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Section 2: Researchers

2.1 PRINCIPAL INVESTIGATOR – STAFF RESEARCH

Title	First name, family name	phone	email

2.2 OTHER INVESTIGATOR/S

Title	First name, family name	phone	email
	<i>Add rows as required</i>		

2.3 PRINCIPAL INVESTIGATOR – STUDENT RESEARCH DEGREE

Title	First name, family name	phone	email
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2.4 SENIOR SUPERVISOR

Title	First name, family name	phone	email
Prof	William Cartwright	03 9925 2423	william.cartwright@rmit.edu.au
Prof	John Handmer	039925 2307	john.handmer@rmit.edu.au

2.5 OTHER INVESTIGATOR/S

Title	First name, family name	phone	email
	<i>Add rows as required</i>		

2.6 School of Mathematical and Geospatial Sciences / SMGS / SEH

¹⁸ Adapted from Queensland Government, Queensland Health “Application for review (HREC or Non-HREC) of low risk research” 2008 and “low impact research”, SET Portfolio, 2008

3. PROJECT DETAILS

3.1	PROPOSED DURATION OF THE WHOLE RESEARCH PROJECT	From :	11 JULY 2005	To:	11 July 2012
3.2	PROPOSED DURATION FOR THE DATA COLLECTION PHASE OF THE RESEARCH PROJECT	From :	Nov 30, 2011	To:	May 31, 2012

Please note: it is a requirement that annual / final reports of your project must be submitted and are due during December for all research projects that have been approved by the CHEAN

The necessary form can be found at:

<http://www.rmit.edu.au/governance/committees/hrec>

3.3 IN PLAIN ENGLISH PROVIDE AN EXECUTIVE SUMMARY OF THE RESEARCH PROJECT

See NHMRC National statement on ethical conduct in human research (2007), section 1

This project investigates learning and time critical decision making in fraught circumstances using scenes made with editors provided by a Commercial off the shelf (COTS) game. The editor *Sandbox2* is included with the *Crisis Wars* Software Development Kit (SDK), (crytek.com) has been used to make movies of bushfires from these scenes set in a virtual Hanging Rock Reserve, in Central Victoria. The movies are viewed in a location based application called *CODE RED: MOBILE*, created with the *7scenes* framework (7scenes.com) and run on *iPhone*.

Up to 40 adult participants (aged 18+) will undertake a scenario training exercise at Hanging Rock *using CODE RED: MOBILE*. Group 1 receive static maps and diagrams about the fire, Group 2 movies with embedded maps and diagrams. Both groups have to decide which of six virtual houses will be safer after a wind change affects the bushfire. The hypothesis is that Group 2 is more likely to choose the correct houses. Participants' performance is also assessed by the analysis of their GPS tracks, questions answered on the mobile device as well as recall of the events in the virtual bushfire.

The research may assist with developing mobile applications for bushfire safety.

3.4 Research Aims and Significance

The aim of the research is to evaluate the potential of visualisations made with COTS game editors and mobile devices to deliver visualisations for learning in a navigation and time sensitive spatial decision making scenario exercise.

The project will help answer the research questions:

- Which theories of game and game design, psychology, spatial cognition, navigation, decision making and learning are most suitable for developing design principles for a time sensitive decision making scenario based game using visualisations on computer and mobile devices?
- What are the design principles for visualisations that best support decision making under stressful conditions?

Dynamic visualisations can impose a high cognitive load through a temporal split-attention effect (Ayres & Sweller, 2005). Static visualisations allow for close inspection and easy review, avoiding the problem of transience with videos. Citing Arguel & Jamet (2009), Van Gog *et al.* (2009) suggest that dynamic visualisations should incorporate static elements, ie freeze a frame in the video and add text and arrows.

The still frames it is argued leave a trace in working memory overcoming the transience problems of dynamic videos. The 7Scenes game framework has video controls, and movies can be reversed or halted.

Van Gog *et al.* (2009) indicate (p 14) that “further research on how to improve the effectiveness of different kinds of dynamic visualizations is still required, but neuroscience findings on the mirror neuron system may help us understand why some dynamic visualisations have proven more effective than others.”

This project researches into ways of making dynamic visualisations more effective, including delivering them at the real world location as well as incorporating static explanatory sections in animations or videos. Pfeiffer *et al.* (2011) found that dynamic-static information, where static items are spliced into a movie was preferable to dynamic or static alone.

The principal hypothesis is that dynamic-static information is preferable to static alone in mobile, location based scenario exercises.

The GPS tracks are classified by fractal score and correlated to the participants’ performance in the exercise. They can be displayed as heatmaps (Fisher, E 2011) and Space Time Cubes (Hagerstrand, T 1970 and Andrienko, N *et al.* 2007). This may contribute to knowledge of methods of visualising and analysing mobile training scenarios and may assist in confirming the principal hypothesis. The GPS tracks analysis may also assist in the design and development of the scenario as well as the implementation of mobile scenario based exercises, thus improving community disaster scenario training.

3.5 Research Methodology

A quantitative approach to the statistical analysis is being used. The inclusion criterion is that participants are over 18 and no other inclusion or exclusion criteria will be incorporated. A sample of at least 20 participants divided into two groups will be tested.

G*Power3 was used by A. Schembri and A. Bedford of the RMIT Statistical Consultancy and showed that sample sizes of 10 and 20 both at a Power ($1-\beta$ err prob) of 0.8, yielded effect sizes respectively of 1.3249474 and 0.9091290. The Cohen’s *d* statistic or effect size, for t test independent samples is considered large at 0.8 and indicates that differences in means between the two groups tested at a sample size of between 10 and 20 for each group will be practically meaningful. (See <http://www.osra.org/itlpj/kotrlikwilliamsspring2003.pdf>)

The α err prob of 0.05 indicates that five out of a hundred times the analysis will falsely reject the null hypothesis. 0.05 is regarded as statistically significant. The results from the G*Power3 analysis is included with the supplementary documents.

3.6 What data collection technique(s) will be used? [Tick as many as apply]

- Survey questionnaire (attach a copy, or if a copy can't be attached, provide details including a citation) ☒
- Web-based survey (you need to complete the document “are you planning a web-based survey” available on the HREC website) ☐
- Interviews or focus groups (attach a question schedule or list of topic areas) ☐
- Observation of participants with their knowledge ☐
- Photographs, audio- or video-recording of interviewees or events with their knowledge and consent ☐

Use of equipment that records biosignals from the body surface and uses an electrical supply in any form (e.g. electroencephalography, electrocardiography, feedback audiometer) ☐

Accessing student data base (IExplore or other) ☐

Other (*Please give details. Use no more than 50 words*): x

Five Questions about bushfire knowledge are triggered at GPS locations in the mobile application. Correct answers are selected from a range of answers offered during the exercise on the iPhone. The answers are recorded to the 7scenes server and retrieved later by the researcher. The selection of which virtual houses they regard as safer are also recorded to the game server at www.7scenes.com.

At the end of the scenario in a debrief participants select the reverse order of events from a randomly ordered list. The reverse order induces some cognitive load. This is completed on paper. It is hypothesised the group with the movies is more likely to be correct.

GPS tracks are also recorded. It is hypothesised that participants who score well on bushfire knowledge, choose the most appropriate safer houses and get the reverse order of events correct will have GPS tracks that are straighter and tend not to wander about aimlessly so much. This will be measured by assigning fractal scores to the track with VFractal (<http://nsac.ca/envsci/staff/vnams/Fractal.htm>) and charting using Space Time Cube with Common GIS (<http://geoanalytics.net/and/papers/iv04.pdf>). The five questions and reverse recount item are provided in the supplementary documents.

3.7

Participants will be sought from the Newham- Woodend community, principally through the Newham and Woodend Landcare Groups and other local organisations. They will be invited to attend for a particular time slot.

Registration and orientation

On arrival participants fill in a registration form (see supplementary documents) providing personal information on: years lived in bushfire prone areas, age group, gender, time of session, furthest education level, whether own a mobile or computer, frequency they play mobile or computer games, and whether have used a GPS. They will be asked for contact details and an emergency contact. A section will ask if they allow photographs to be taken of them during the exercise. It will be explained that their name will never be published anywhere nor their details revealed.

Participants are informed that the scenario is set somewhat in the future for the purposes of the exercise. Housing development has been allowed on parts of the Hanging Rock Reserve.

They are given a number. This number will be used in a question they are asked at the beginning of *CODE RED: MOBILE*. This ensures that they can be matched to their session recorded at the 7scenes server. Their number assigns them to Group 1 or 2. They are informed that participants are testing several types of *CODE RED: MOBILE* in order to improve it. They are asked not to help each other but to use the assistants available on a mobile phone, using the participant's private phone, not the provided *iPhone*.

There are four *iPhones* available allowing four participants to take part at once. Half an hour will be allowed for training in the use of the device and the application. Each participant also carries a GPS device, this will only be adjusted by the researcher and assistants.

They will be staggered at 15 minute intervals. They should finish in 60- 90 minutes. Several people will be available on mobile phone at Hanging Rock for anyone who needs assistance. There are toilet and cafe facilities at Hanging Rock. There is a 30 minute gap between sessions, during this time the next group is trained and the GPS is set up to record the next track.

At certain locations a map is triggered showing where each of the four participants by number must go next. The map may show where they can find five icons appropriate to them. They may find another person in their area if that person has not completed the five tasks yet. They are instructed to not go near or open the 5 icons that are in another area. If for example they have to go to the toilet, they are asked to skirt round their banned areas.

Phase One

The first phase or Orientation Phase occurs in two clear areas to the south of Hanging Rock. Each has five icons on the device at five locations. In this phase basic questions about bushfires are asked on the mobile device. Each participant is directed to one of the two areas. They have a paper map showing them which is their area. Participants in both areas will be doing the same five questions. An assistant will make sure the participants do not stray into each others' area. This gets the participants used to seeing other participants in completely different areas. It will give the impression of more versions of the exercise going on than there really is.

Phase Two

After this, in the Learning Phase, participants according to their paper map will be directed to go northwards up the racetrack. Here they will encounter no information or tasks but will continue to orient themselves. Group 2 is instructed to turn left or west at the track cross over, just passed the race goers enclosed area. They then go to the west a little and turn northwards up the North South asphalt laneway. From here they find the northern most movie icon and watch the first movie plus other information. Then they head back south down the laneway viewing the other two movies at their respective locations. Meanwhile Group 1 goes to the northern end of the racetrack straight and views the static information saved in a movie icon, showing maps and diagram on the fire's point of origin. They then go back south leaving the racetrack going eastwards where the cross over is located and entering the inner area of the racetrack. From here heading south they visit two more movie icons where the next two sources of static information are viewed.

This allows each group to see two versions of information about the bushfire event both saved as movies but one featuring only static information, the other movie with spliced in static information. With this information both groups learn about the fictional weather and fire danger for the day as well as the type of fuel and fuel loads occurring at Hanging Rock in the scenario. The three sets of information, of whichever type, show the origin of the fire, the passing of the fire from north to south of the Hanging Rock feature, and finally the wind change and the spread of the fire to the east where the virtual houses are located.

Both groups then reach the centre of the cricket oval within the racetrack perimeter. Here an icon reveals text which sets the main problem to be solved.

They are informed they have to decide which of six virtual houses will be safest after the wind change has turned the bushfire so that it now heads east. They can see the icons representing the houses on the device screen. Each must be visited. They are asked at each house to record if that house is likely to be safe or not? These answers are relayed to the server.

When this is completed they return to the cricket club rooms at the edge of the oval. Here they complete the debrief sheet which asks for events and details of the scenario to be numbered in reverse order (See supplementary documents). The reverse order adds cognitive load and correct results may show correlation with their tracks fractal score. Those with a better idea of the event order are likely better navigators overall with a lower fractal score.

Finally some refreshments are provided and they are thanked for their participation.

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3.8 Explain how data will be analysed (50 words)

GPS tracks' fractal score is calculated using *VFractal* (See: <http://nsac.ca/envsci/staff/vnams/Fractal.htm>). Fractal scores are displayed with heatmaps and Space Time Cubes (*CommonGIS*) of GPS tracks. These analyses are correlated with Group 1 or 2 versions of the provided information, statistics for reverse recounts, scores on bushfire questions, background information of participants and the correct house choices of the two groups.

3.9 Provide a list of the references that have been used in this application

- Andrienko, G, Andrienko, N, and Wrobel, S 2007 'Visual analytics tools for analysis of movement data', *ACM SIGKDD Explorations*, vol. 9, no. 2, pp.38-46.
- Arguel, A, Jamet, E 2009, 'Using video and static pictures to improve learning of procedural contents', *Computers in Human Behavior*, vol. 25, no. 2, pp. 354-359.
- Ayres, P., & Sweller, J 2005, 'The split-attention principle in multimedia learning' in R. E. Mayer (ed.), *The Cambridge Handbook of Multimedia Learning*, New York: Cambridge University Press, New York, pp. 135-146
- Fischer, E 2011: <http://www.flickr.com/photos/walkingsf/4671594023/in/set-72157624209158632>
- Hägerstrand, T 1970, 'What about people in regional science?', *Papers of the Regional Science Association*, vol. 24, no. 1, pp.6-21.
- Pfeiffer, VDI, Scheiter, H, Kühl, T & Gemballa, S 2011, 'Learning How to Identify Species in a Situated Learning Scenario: Using Dynamic-Static Visualizations to Prepare Students for Their Visit to The Aquarium', *Eurasia Journal of Mathematics, Science & Technology Education*, vol. 7, no. 2, pp.135-147.
- Van Gog, T, Paas, F, Marcus, N, Ayres, P, & Sweller, J 2009, 'The mirror-neuron system and observational learning: Implications for the effectiveness of dynamic visualizations', *Educational Psychology Review*, vol. 21, pp. 21-30.
- Websites:
- <http://www.osra.org/itlpj/kotrlikwilliamsspring2003.pdf>
- <http://nsac.ca/envsci/staff/vnams/Fractal.htm>

4. RESEARCHERS' QUALIFICATIONS, EXPERIENCE AND SKILLS

For each of the researchers listed in section 2.1 and 2.2 list their academic qualifications and briefly outline experience and skills relevant to this project (50 words for each investigator)

Patrick Brian Quinn - Principal investigator (Student Research Degree)

Academic qualifications:

B.Sc. (Hons), University of London

Dip.Ed., University of Melbourne

M.App.Sc. (Hons) University of Melbourne

Research experience and skills:

The Bachelor of Science (Honours) completed 1971 had a geomorphology project mapping an overspill channel of Glacial Lough Neagh in Northern Ireland. Also a Geology mapping project for a week in Donegal, Ireland.

A Preliminary M.Sc at University of Melbourne included a research project completed in 1975 which used Symap on the mainframe computer. Geomorphological and other data was collected in the field. A computer map was made using Principal Component Analysis to regionalise the landscapes of part of the Macedon Ranges.

The M.App.Sc included a research project using COTS game editors to make a game for secondary students involving geographic site and situation activities. The game was made with the editor provided with Tribes2. It was a research project associated with classwork on GIS, Visualisation, C programming and Databases.

Prof. William Cartwright, PhD EdD FRGS FBCartS HonFMSIA HonFSSI – Senior supervisor

William Cartwright is Professor of Cartography and Geographical Visualization at RMIT. He has published over 300 academic papers. His major research interest is the application of integrated media to cartography and the exploration of different metaphorical approaches to the depiction of geographical information.

William Cartwright is Professor of Cartography and Geographical Visualization in the School of Mathematical and Geospatial Sciences at RMIT University, Australia. He joined the University after spending a number of years in both the government and private sectors of the mapping industry. He is President of the International Cartographic Association. He is a Fellow of the Royal Geographical Society, a Fellow of the British Cartographic Society, an Honorary Fellow of the Mapping Sciences Institute Australia and an Honorary Fellow of the Surveying and Spatial Sciences Institute. He holds a Doctor of Philosophy from the University of Melbourne and a Doctor of Education from RMIT University.

He has six other university qualifications - in the fields of cartography, applied science, education, media studies, information and communication technology and graphic design. He is the author of over 300 academic papers. His major research interest is the application of integrated media to cartography and the exploration of different metaphorical approaches to the depiction of geographical information.

Prof John Handmer – Secondary supervisor

Professor Handmer is a Principal Scientific Adviser at the Bushfire CRC and has been the Program Leader of the Safe Prevention, Preparation and Suppression program since 2003. He is also the Director of Centre for Risk and Community Safety at RMIT University.

Professor Handmer was a leading researcher and adviser to the Bushfire CRC Research Taskforce immediately after the Black Saturday fires.

During the subsequent Royal Commission, Professor Handmer was an expert witness and was requested by the Royal Commission to conduct several in-depth analyses that directly contributed to the final deliberations.

5. PARTICIPANT DETAILS

5.1 PARTICIPANT DATA

Identified ☐ Potentially identifiable (coded) ☐ non-
identifiable/anonymous ☒

5.2 TARGET PARTICIPANT GROUP

Students of this University ☐ Students of one or more other universities ☐

A specific target group (please identify in section 5.3) ☐ People under 18 years (please detail in section 5.3) ☐

No special characteristics ☐ Persons on a data base that has been sourced with permission ☐

Other (please give details – up to 50 words): X

Participants will be adults and mostly residents of the Macedon Ranges Shire.

5.3 NUMBER, AGE RANGE AND SOURCE OF PARTICIPANTS

Provide number, age range and source of participants; indicate how many groups will be used and describe the characteristics of each group. Do you have any exclusion criteria?

Up to 40 participants all aged over 18.

5.4 EXPLAIN HOW YOU WILL RECRUIT YOUR PARTICIPANTS AND INVITE THEM TO PARTICIPATE

Include in your explanation the precise details of the recruitment method (e.g. direct approach, networking, advertisements/flyers, accessing a database (are you authorised), talking to a group)

Friends, local people and members of Landcare and other Groups in Macedon Ranges Shire.

5.4.1 Explain, if applicable, the steps to be taken to ensure that participation will be purely voluntary and not influenced by, for example, the teacher/student, doctor/patient, manager/subordinate relationship (where there is a dependency relationship between the researcher and participant).

Community group activities are voluntary and no one will be disadvantaged by not turning up or not volunteering for the exercise.

5.4.2 Detail, if applicable, the steps to be taken to ensure that the conduct of the research will not interfere with the primary teaching role of the class, provision of normal clinical care or conduct of normal business.

N/a

5.4.3 Include any steps that may be necessary to respect the cultural sensitivities of participants.

N/a

5.5 WORKING WITH CHILDREN CHECK

If you specifically intend to recruit children as participants, have the relevant members of the research team completed a Working with Children (WWC) Check?

Yes

No

☐

6. RESEARCH INTO TEACHING PRACTICE

6.1 IS THIS RESEARCH PROJECT SPECIFIC TO RESEARCH INTO UNIVERSITY TEACHING PRACTICE?

Yes ☐ No ☒

(If YES, please go to 6.2. If NO, please move to section 7)

6.2 Have you sought permission to recruit students for your research from the course co-ordinator, discipline leader or Head of School¹⁹?

(Please note: it is important to consider the degree of exposure of students to staff research into teaching practice activities)

Yes ☐ No ☒

6.3 Do you intend to use class time to undertake your research activities?

Yes ☐ No ☒

6.3.1 If yes, please explain why this is necessary and detail how much time will be taken to complete research activities.

6.3.2 Have you received written permission from your Discipline Leader or Head of School to use class time to conduct your research activities?

Yes ☐ No ☒

6.4 Do you intend to use student assessment grades as part of your data?

Yes ☐ No ☒

6.4.1 If yes, you must ensure that students are aware that you will access their assessment grades as part of your data. You must explicitly state, in the PLS, that student progress will NOT be affected by their participation / non-participation in your research.

Please detail the steps you have taken to ensure that students are aware that their participation / non-participation in your research will not affect their assessment scores or progress through their program of study.

6.5 Do you intend to use student assessment tasks, or any other forms of activity, or participation in them, as part of your data?

Yes ☐ No ☒

If you answer YES, you must respond to 6.5.1 and 6.5.2

¹⁹ Please note: Final approval will only be given when appropriate approvals have been provided to the CHEAN

6.5.1 If yes, you must ensure that students are given an opportunity to “opt-in” to the research-associated assessment task or other forms of activity or contribution. Are students given the option to opt-in to the research associated assessment task or other forms of activity or contribution?

Yes ☐ No ☐

6.5.2 If you answered YES to 6.5.1, please describe the strategy you will use to allow students to “opt in” to the research associated assessment task. Note too that this information must be included in your information sheet (plain language statement).

6.5.3 A second strategy is that the student is given an opportunity to consent to the use of information associated with their assessment task. Are students given an opportunity to consent to the use of information associated with their assessment task?

Yes ☐ No ☐

6.6 Do you intend to access RMIT student databases (e.g. IExplore, Learning Hub email system / or similar) as part of your data collection or as a method to recruit students for your research?

Yes ☐ No ☒

6.6.1 Are you authorised to access the specific database for the purposes of your research project?

Yes ☐ No ☐

If you responded yes to section 6.6, you must explicitly state this in the PLS.

Does the PLS explicitly state that you have / will access RMIT student databases as part of your data collection or as a method to recruit students for your research

Yes ☐ No ☐

6.7 Do you intend to use CES data as part of your research data?

Yes ☐ No ☐

6.7.1 If YES, you must inform students that their information will be used for research purposes.

Does the PLS inform students that their information will be used for research purposes as well as for quality assurance purposes?

Yes ☐ No ☐

6.8 Do you intend to use student Blogs / Wikis or any other interactive IT conversational tool as part of your data collection method?

Yes ☐ No ☒

6.8.1 If YES, you must use the RMIT “statement to be included on Blogs” at the front end of your IT interactive conversational tool. Have you accessed / or will access and use/d the RMIT “statement to be included on Blogs”

Yes ☐ No ☐

Please note: Students must be informed if their participation will form part of aggregated data, and advised that before any individual contribution is quoted, specific permission will be sought from them

7. INFORMATION FOR PARTICIPANTS AND INFORMED CONSENT

7.1 INFORMATION SHEET

Participants will be given an information sheet that contains all items listed in Attachment A

Please attach copy of your information sheet if applicable.

7.2 CONSENT FORM

Consent form not required

X

Participants sign a consent form

Consent assumed if participants return a questionnaire X

If using a consent form, please attach copy.

8.. PRIVACY AND CONFIDENTIALITY

8.1 DATA STORAGE

Data will be stored in a secure location

Where will the data be stored?

Detail security arrangements for storage of data. The Data will be stored in a secure facility at RMIT and destroyed after 5 years.

Data will be stored for 5 years after publication of research findings

Only the researchers will have access to the data

Data will only be used for the purposes described in the participant information sheet

If any of these boxes is not checked, please explain the arrangements that will apply.

8.2 REPORTING PROJECT OUTCOMES

(a) Will the project outcomes be made public at the end of the project?

YES

NO

The results will be published in a PhD thesis and papers provided to professional journals. Papers may be presented at conferences. Additionally, a final copy of the PhD thesis will be added to the Geospatial Science thesis collection, and a copy will be available to

students at the RMIT library.

- (b) Will a plain language report of the project outcomes be available to participants at the end of the project?

X YES NO The participants will be able to access the PhD thesis by request and a summary of the results will be sent to all participants.

9. Funding and Finance

Researchers should include any source of funding (e.g. departmental, commercial, non-commercial, government)

See NHMRC National statement on ethical conduct in human research (2007), section 5.4

- (a) Has this research received any research funding or is this submission being made as part of an application for research funding

Yes ☐ No ☒

If yes, what is the source of funding

- (b) Will the researcher receive any remuneration and/or in kind funding to perform this research?

Yes No X

If yes, give details

- (c) Will participants receive any payment or expenses for participation in the research?

Yes ☐ No ☒

If yes, give details

10. OTHER APPROVALS

Is this protocol being submitted or has it been previously submitted to another ethics committee?

Yes ☐ No ☒

If yes, give details of other institutions involved; the approval status and details of required amendments

11. DECLARATION BY RESEARCHERS

I/We have read the NH&MRC National Statement on Ethical Conduct in Human Research (2007), and accept responsibility for the conduct of the research detailed in this application in accordance with the principles contained in the National Statement and any other conditions laid down by the relevant RMIT Human Research Ethics Sub-Committee.

Name: _____ Date: 21st October, 2011

(Signature of Principal Investigator)

Name: _____ Date: _____

(Signature of other investigator or senior supervisor if applicable)

Copy, paste and complete additional signature boxes to enable all co-investigators to sign.

Declaration by the Supervisor (if not an investigator)

I have informed the student of their responsibility to undertake this research in a manner that conforms with the NH&MRC National Statement on Ethical Conduct in Human Research 2007, and any conditions of approval of this research by the RMIT College Human Advisory network.

Name: _____ Date: _____

(Signature of senior supervisor)

Declaration by the Head of School:

The project set out in the attached application, including the adequacy of its research design and compliance with recognised ethical standards, has the approval of the School. I certify that I am prepared to have this project undertaken in my School/Centre/Unit.

Name: _____ **Date:** _____

(Signature of Head of School or approved delegate)

School/Centre:

Extn:

INFORMATION SHEET (Plain Language Statement) (if applicable)**Confirm that information sheet will:**

	YES	NOT APPLICABLE
1. be printed on College / University letterhead as required	☒	
2. include clear identification of the University, the School(s) involved, the project title, the principal and all other researchers (including contact details and qualifications of investigators), and the study level if it is a student research project.	☒	
3. state the aims of the research project	☒	
4. advise that the project has received clearance from the HREC	☒	
5. advise why the participant has been approached (random, sampling method, specific target group, whether their contact details have been obtained from another source and who provided permission for this)	☒	
6. provide details of what will be required of participants (e.g., involvement in interviews, completion of questionnaire, audio/video-taping of events), and estimated time commitment	☒	
7. any risks/benefits to participants involved	☒	
8. state that involvement in the project is voluntary and that participants are free to withdraw consent at any time, and to withdraw any unprocessed data previously supplied	☒	
9. include a clear statement that involvement in the project will not affect ongoing assessment/grades/treatment	☐	☒
10. provide advice about what will happen to the information provided including arrangements to be made to protect confidentiality of data and secure storage of data	☒	
11. provide advice as to whether or not data is to be destroyed after a minimum period	☒	
12. state how privacy of the individual will be protected in any publication of the information (i.e. protecting the anonymity of participants)	☒	
13. provide advice regarding inherent risks associated with participation in research that uses web-based surveys	☐	☒
14. provide in the footer, the project HREC number, date and version of the information sheet	☒	
15. provide advice that if participants have any complaints about the conduct of this research project that they can contact the Executive Officer, RMIT Human Research Ethics Committee, see http://www.rmit.edu.au/rd/hrec_complaints	☒	

Please attach a copy of your information sheet to your application