Making Waves

– a Design Concept for Reactive Tsunami Education

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Abstract

In New Zealand the public has access to a range of educational material to assist with understanding tsunamis and their inundation zones. However much of this material is hard to find, is of limited availability, and is also likely to be limited in its effectiveness because of its non-interactive design.

This applied design research project explores the capacity of communication design to deliver clearer information about tsunamis to the general public. It uses animated information graphics and mobile media in the design of an educational tool for disaster awareness.

The new tool developed during the project offers the current generation of technologically-enabled users more ways to learn, and access to more information, about tsunamis. The tool also combines an educational function and a warning function. Design aspects are based on an evaluation of how warning messages are received and understood by intended audiences. The project has focused on the use of existing warning material for visual communication.

The project is based on research into information design theory: how a rich texture of data in a comparative context can be implemented in a complex arena such as disaster education, and how good design can cater for diverse cognitive reception or learning styles. The project incorporates this theory into the design of an interface with the objectives of

(I) offering an alternative and attractive way of visualising inundation zones and other information to an audience that may be indifferent to existing information and advice about tsunamis, and

(II) utilising mobile devices and its distinct technological advantages of location and communication access to enable the dissemination of warning messages.

These objectives combine to offer future potential as an additional communication channel for a directed and immediate warning through use of GPS data and geo location, plus reactive user interface design adapting to an emergency situation.

Content

1.0

"It sometimes does us a power of good to remind ourselves that we live on two volcanic rocks, where two tectonic plates meet in a somewhat lonely stretch of windswept ocean just above the Roaring Forties. If you want drama you've come to the right place".

R.H. Sir Geoffrey Palmer

Since the 2004 Indonesian Boxing Day tsunami, the Pacific Rim region has been subject to multiple warnings and at least three significant disaster events including tsunamis in Samoa in 2009 and Japan in 2011. Since 2004, tsunami awareness and resilience has greatly improved. However, a great number of coastal communities have continued to be affected by subsequent events.

This exegesis introduces and presents a design-led research project which includes analysis of literature related to tsunami warnings, and uses animated information graphics and mobile media in the design of an educational tool for disaster awareness.

The new tool offers opportunities to increase awareness and access to relevant information through mobile technology. The research culminates in a design prototype using the location of Wellington, New Zealand as an example and demonstrates the possibilities of disaster mitigation through communication design. By placing the graphics in a local and personalised context, it is anticipated that education and warning methods will result in better evacuation practices, capable of lowering the potential number of fatalities.

Current educational material on the subject of tsunami warnings consists of a variety of localised signage along the coast, which indicates escape routes. Additional information is accessible online through government websites. These materials are fixed, printed and/or non-interactive, so a user must physically visit the location to see it in context or resort to an online search for more information. This project proposes to publicise relevant education on web-enabled mobile devices; it seeks to communicate in a dynamic manner.

The research was initiated by three questions:

(I) How do you educate, inform, warn and assist people who have never experienced danger before?

(II) What role can interactive information design have in tsunami education to increase awareness, change behaviour and speed up preparation?

(III) Can information design on mobile devices help, and how does information have to be adapted to be effective in an emergency?

A review and evaluation of the tsunami education and warning material currently available led to the conclusion that redesigning this existing material was likely to be the most effective way to increase the public's understanding and acceptance of new, mobile tool for delivering the information.

Mobile devices offer great advantages over stationery communication channels as they can provide localised maps and global positioning systems (GPS). This design research project aims to utilise mobile devices to distribute relevant information right to (quite literally) someone's fingertips. It incorporates local relevance to present a more accurate insight for the individual. Developing this concept further, the information does not need to be limited to an awareness campaign only, but may also be used to act as a warning and guiding system, consisting of a diagnosis and assistance tool in a real event. In an emergency, information design and user interface design will have to develop accordingly, as perception and people's body reaction in a distress situation will require an interface capable of adapting to the changing physical and cognitive circumstances. Risk maps will need to transform into response maps and regular features of the interface will have to adapt to a user with limited time, initiative and attention.

This project aimed to harness the distinct technological advantages of mobile communication devices and combine them with recognised principles of information design and user interface design to create supporting education material for increasing tsunami awareness and resilience.

1.1 Defining the Research Objectives

1.1.1 Methods and Processes

Tsunami education in New Zealand currently focuses on raising awareness. Dr Stefan Reese, Risk Engineer for Natural Hazards at the National Institute of Water and Atmospheric Research (NIWA) reported in an interview that a multitude of education methods, in conjunction with continuous repetition, is the current option to increase awareness.[2] However, I theorise that this 'scattergun' approach has its limitations, as evidenced by the (lack of) response of Whitianga's population to multiple false alarms in May 2012. While the first alarm had been triggered instead of a fire alarm, the second alarm is believed to have been set off unwittingly by a cleaner. After a third false alarm in early June 2012 due to a faulty battery, the system has been switched off until the issues can be resolved.[3]

Another approach of educating the public consists of blue road markings in Wellington's Island Bay suburb. These serve to indicate tsunami safe zones, but have been installed only in Island Bay leaving the false impression that other coastal areas are unlikely to be affected.

1.1.2 Divergence

By accumulating data from reports on the current state of disaster prevention, I was able to develop models of communication methods and design approaches. My research led to the conclusion that existing resources are generalised and inconsistent, and as such, communicate important messages poorly. My research material has had to be based on secondary and tertiary sources like news footage, educational websites and applications as well as billboards and leaflets. I collected both qualitative and quantitative data, and arranged these visually along a set of parameters. This enabled quick access, evaluation and experimentation with the method. The research included evaluation of possible visual warnings and concepts competing in the same physical or medial settings.

1.1.3 Developing and Testing Prototypes

Developing prototypes and testing them on the targeted user/audience enabled me to see the bigger picture and let me consider a range of ethical issues. For example, the research probed how different demographic groups may react to a 'generalised' warning message, and also whether it is ethical to focus warnings on more populated communities or more affected areas, effectively not directly serving the entire community at large.

Verifying and validating the design research included interviews, research by observation, user-testing and workshops with geological survey scientists and students of graphic design. These interviews and workshops progressed under the auspices of Massey University Human Ethics Policy.

The aim was to research the visual communication content of the project appropriate to a specific context and catering to a range of demographic, community and environmental needs. In addition,the aim was to develop a user interface that worked in a clear, effective, timely and accessible way. Re-evaluation of the outcomes has been an essential part of the research process which has led to a deeper understanding of the subject. It has also pointed to evident gaps in the design solution that forecast future research directions and opportunities.

2.0

2.1 Tsunami

Unlike earthquake prediction, tsunami prediction is possible but its accuracy depends on a wide range of factors. In general, the longer the travel time of the tsunami, the more precise the forecasted impact will be. According to the NZ Ministry of Civil Defence and Emergency Management (CDEM) website (http://www.civildefence.govt.nz), tsunamis in New Zealand are classified into three categories based on their origin: distant, regional and local. Usually more than three hours away, distant tsunamis allow for a wide range of timely evacuation measures. Regional tsunamis are those that are one to three hours away, whereas local tsunamis are very dangerous; they leave only a few minutes for issuing a warning. Successful warnings and evacuation are unlikely in the case of a local event, whereas with distant and regional tsunami there is a chance to disseminate early warning messages. These may give coastal communities valuable time, enabling them to escape and survive.

2.1.1 Background/History

The history of tsunamis dates back many centuries. In a letter to Tacitus in 79AD, Pliny the Younger describes how the eruption of Mount Vesuvius on 24th December resulted not only in a devastating ash cloud burying the city of Pompeii, but also how the receding shoreline indicated signs of a tsunami.[4] In Japan today, we can find 600-year old stone markers still acting as a reminder to tsunamis that happened all those years ago. Between 2004 and 2013 the world has been confronted with at least three major tsunamis in the wider Pacific region. The 2004 Boxing Day tsunami demonstrated how large areas of the Pacific Rim coastline are vulnerable to tsunami and coastal inundation.

New Zealand's shoreline is known to be similarly vulnerable. In 1848 a large earthquake in the Marlborough Sounds in the South Island raised awareness of the level of risk to potential building damage and loss of life and led the New Zealand government to reconsider building practices. The benefits of insisting on wooden structures became apparent in 1855 when the most powerful earthquake recorded (up until this time) not only changed the face and topology of Wellington's landscape but also resulted in a tsunami flooding lower-lying buildings and destroying structures along the coastline. Surprisingly few people were injured in this event; the estimated number of casualties varies between five and nine. Unfortunately, twenty to thirty years later, the memory of these events had faded and there is evidence to suggest that standards of building safety declined as well. Disaster awareness reached an all time low, as described in an article in the New Zealand Official Yearbook 1923:

> *"Earthquakes in New Zealand are rather a matter of scientific interest than a subject for alarm."*[5]

Subsequent New Zealand governments and research facilities have abandoned the notion of earthquakes being a 'scientific curiosity' and have accepted that the country's unique geology calls for much greater attention and understanding. Most recently, the February 2011 Christchurch earthquake has increased the focus on improving building codes and construction practices. But what impact did it have on tsunami practices?

Geographic surveys have shown that New Zealand has experienced a long history of tsunamis, but since it has only been populated for the last 200 years, impacts and casualties have been very low. However, international events in recent years have demonstrated a general need for tsunami awareness and preparation. In the last eight years, tsunamis affecting coastal communities of the Pacific Rim have caused over 300,000 deaths and irreparable damage to infrastructure. Media exposure of these events has raised tsunami awareness overall and sparked numerous reconsiderations in land planning and use as well as the development and implementation of the 2005 – 2015 Hyogo Framework for action initiated by the United Nations.[7] The aim of this framework was to promote a strategic and systematic approach to reducing vulnerabilities and risks to hazards. Additionally it underscored the need for, and identified ways of, building the

resilience of nations and communities to disasters.

Key areas the Hyogo Framework identified are:

(I) Governance: organisational, legal and policy frameworks

(II) Risk identification, assessment, monitoring and early warning

(III) Knowledge management and education

(IV) Reducing underlying risk factors

(IV) Preparedness for effective response and recovery. (2)[7]

These areas are overall indicators of where disaster risk reduction must move to, with the aim of building a continuum of strategies to increase its effectiveness into the future.

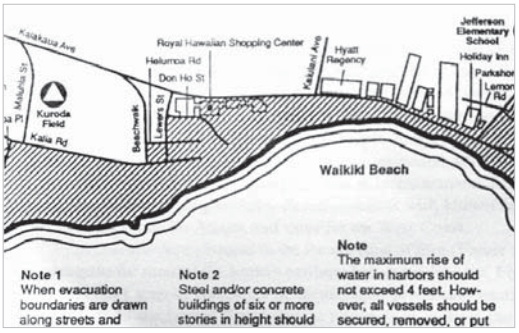


Fig.1
Hawaii's inundation risk map in the White Pages pointing out landmarks and Civil Defense shelter on Waikiki Beach.

2.1.2 Warning Systems

Tsunami awareness and education is not just a feature of modern times as shown by the inscription on the 600 year old Japanese marker stones:

> *"High dwellings are the peace and harmony of our descendants, remember the calamity of the great tsunamis. Do not build any homes below this point."*[6]

There is a wide range of educational methods and material available internationally, ranging from Hawaii's inundation maps printed in the telephone White Pages covering coastal communities (Fig.1), to internationally recognised signs indicating escape routes, and sophisticated early warning systems capable of disseminating a tsunami-centric warning message over a wide range of digital media.

The 2004 Boxing Day tsunami in Indonesia started a worldwide effort to decrease the potential number of casualties in future events by improving early warning systems. These systems consist of a network of buoys, seismographs, GPS-receiver and tide level recorders. Since they were introduced in 2008, the new systems have successfully issued warnings in ten individual cases of potentially harmful tsunami.[8] News coverage of these events, including the Samoan tsunami in 2009 and the Tohoku tsunami in 2011, has continued to raise awareness around the globe. Media exposure of these kinds of disaster has contributed to coastal communities reviewing their warning processes and level of preparedness. A number of New Zealand's coastal communities have taken action, as mentioned in CDEM final report of the Exercise Tangaroa. (26,36)[9]

The Japanese Meteorological Agency (JMA) invested millions in an early tsunami warning system and was considered a world leader in understanding and evaluating tsunami risk in a timely manner. On 11th March 2011 the JMA estimated a three meter wave was approaching Tohuku's shores. Sadly the actual wave measured ten meters and claimed the lives of 20,000 people. In the aftermath of the tsunami, Akira Nagai, head of the JMA, evaluated the damage and the practices in place and subsequently admitted that the wrong forecast lead to slow communication of the event. The revised early warning system now acknowledges the unpredictable nature of natural disasters as well as the difficulty of translating this knowledge into

public information.[10] As a result the agency will no longer put a number to tsunami height following a large-scale earthquake, but rather will warn about the possibility of a huge tsunami. The revised Japanese system is still capable of issuing a warning within three minutes, but in an attempt to avoid misunderstanding and underestimated readings, it will cut the number of wave categories from eight to five. Fumihiko Imamura, a tsunami specialist at the Disaster Control Research Center of Tohoku University commented on the on-going revision of the plans:

> *"Warnings could be issued with precise maps on computers, televisions or mobile phones, and would help to overcome the difficulty people have in interpreting warnings … What we do is natural science. But how people read these numbers is a difficult problem that requires human science. We need more research on that."*[10]

2.1.3 New Zealand's National Context

In New Zealand, tsunami education for the public consists of brochures and billboards composed primarily of local inundation maps displaying levels of inundation, and illustrated in variegated colours. These are followed by explanations of different types of tsunami warnings. Further advice gives guidelines for preparation to cope with the event before, during and after a tsunami has reached the shore.

Dr Terry Webb, (2005, 1) Director of Division for Natural Hazards at GNS Science writes that an individual's critical awareness and risk perception is an important preliminary requirement in preparing for a disaster. In a survey covered in Webb's report, communities were asked to name the top hazard that could affect them in the future. Only a minority rated tsunami (82). This national perception level survey, undertaken in 2003 by the Institute of Geological and Nuclear Sciences, revealed that over two-thirds of the public did not know if there was a local tsunami warning system in place (83). This survey points to the urgency and relevance of improving tsunami warning education.[1]

Tsunami-related information on Wellington's coastline

I undertook a review of the mode of measuring and forecasting tsunami risk in a local Wellington context, and evaluated research (including an interview with Dr Stefan Reese, Risk Engineer for Natural Hazards from NIWA). From this I concluded that a multitude of education methods, combined with the right channels of communication and continuous repetition, can increase public awareness of tsunami risk.[2]

One scheme to raise awareness in the Wellington suburb of Island Bay consists of blue lines painted across streets to indicate topographical safe zones (Fig.2). Although similar concepts turned out to be inaccurate and ineffective in the 2011 Tohoku earthquake, this experiment with the blue lines prompted an on-going discussion amongst Wellington's coastal communities. Discussion included doubts from local residents who were concerned about property devaluation within the 'danger zone' or the markings indicating a possible spot for sightseeing during a tsunami event. More related educational

Fig.2
A static tsunami education method in Wellington's Island bay suburb does not only serve as a constant reminder for escape routes, it also initiated a lively discussion and consequently raising awareness.

information and material can be accessed from a public display board along the Island Bay coastline, which includes inundation maps and information about tsunami theory. The same material is available (albeit hard to find) on government websites.[11]

The analysis of these findings made it apparent to me that the positive aspect of a wide and comprehensive range of available educational material also results in weaknesses, due to the inconsistency of visual communication and language. For example, using blue and white colours and legible typography, Island Bay's road markings are designed to adhere to the International Organization for Standardization (ISO) warning signage. (Fig.3) On the other hand, online brochures in PDF format indicate inundation zones by using the colours of CDEM – blue and yellow. These design elements ignore the detrimental effect the contrast has on the legibility of the content. (Fig.4) The same inundation maps displayed on the information billboard in Island Bay use lighter colours but confuse the design by ignoring a grid and adding superfluous design elements to text boxes that distract from content and add a contradictory playful feel to a serious topic. (Fig.5)

The recent history of tsunami, with news footage of disaster events developing in real time and scientific modelling information relative to coastal topography, leads me to conclude that it is not only possible to give advance warning of a tsunami within a given timeframe, but it is also possible for communities to plan and prepare for a potential scenario. Information design and technology turn out to be fundamental to the successful dissemination of educational material that effectively prepares those living in inundation zones. Information design and technology can also provide live data, information and instructions to those in a disaster vulnerable zone.

National information and education resources

New Zealand's tsunami education and warning dissemination is managed and coordinated by CDEM. To date, only the Boxing Day tsunami of 2004 has triggered a wider public awareness and an

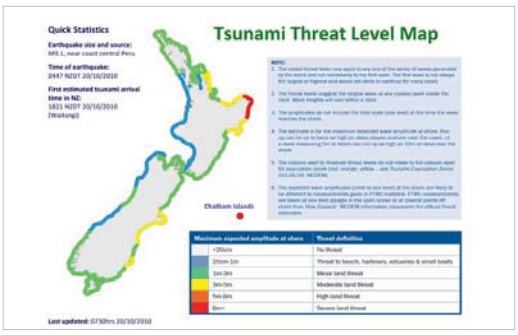
Fig.3
ISO standard tsunami signage.

Fig.4
Downloadable brochure in pdf format.

Fig.5
Education billboard in Wellington's suburb Island Bay.

acknowledgement of New Zealand's vulnerability. Television reports and footage of this event sparked off a wide range of campaigns ranging from TV ads and web resources such as getthru.govt.nz, a movie (Aftershock)[12] and a number of non-public exercises (Exercise Tangaroa, Pacific Wave).[13] However, specific tsunami education is mostly self-directed, integrated and mentioned in the official earthquake education. While most educational material is accessible online, there is more in the form of threat level maps which are disseminated in a real scenario where New Zealand's coastline can be affected. The public will receive one of about three-hundred of these pre-rendered maps based on simulated scenarios through the official warning channels like TV and CDEM website. (Fig.6) These maps are specifically designed to instantly recognise a threat to a specific area making it easier to judge an impact. There is a need to distinguish

Fig.6
New Zealand's tsunami threat level maps showing more in-depth knowledge of coasts likely to be affected.



between generalised educational information and context specific information such as threat level maps and statistics published with the intention to disseminate a timely warning in an actual event. To be clear, in the case of an actual event, the current warning practice distributes pre-simulated scenario-based maps; this information is not specific to the actual factors of the real event nor dynamically relevant.

The tsunami evacuation maps prepared by GNS science for CDEM groups are published to educate about possible tsunami inundation in populated coastal areas and serve to identify key escape routes. Additionally, coastal communities indicate escape routes with statutory ISO signage. The majority of these communication designs are easy to understand and self-explanatory (which is good when time is scarce and a tsunami is imminent) but lack consistency and accessibility. It becomes apparent that risk maps are the fundamental feature of this material, but the available scale means they lack of detail – an important aspect in regard to design.

'Riskscape' is a powerful interactive tool developed by NIWA and GNS Science to evaluate regional disaster risk to building, infrastructure and societal inventories. While very effective in this role, 'Riskscape' does not actively contribute to the public's understanding and preparedness for a possible tsunami since it was mainly developed as a tool for government agencies and research institutions. Since Riskscape is capable of calculating risks associated with disaster and modelling possible damage to infrastructure, it also offers the chance to inform communities about how they can prepare and minimise risk from a tsunami event.

Improving on what is currently available

In this project, I propose to replace the current varied and inconsistent approach to providing information with a consistent visual language that is more efficient in repeating, strengthening and imposing a message beyond the pictures of recent disasters. My design uses visual communication and technology to assist in clarifying disaster preparedness to a possibly complacent demographic.

2.2 Information Design

2.2.1 The Importance of Identifying the right Parameters in Information Design

Edward R. Tufte is a professor of political science, statistics and computer science at Yale University known for his writings on information design and as pioneer in data visualisation. He presents an example showing the accumulation of data on a map, which aided in finding the source of a cholera epidemic in London during September 1854. Suspecting contaminated water supplies, John Snow plotted a list of 83 deaths on a map and concluded that most deaths were centred around a water pump on Broad Street. After removing the handle from the pump (the alleged source of the epidemic) the death toll dwindled and eventually came to a halt in this area. Snow's successful mapping made use of combined data with a traditional way-finding tool. His method led to the discovery that cholera is a waterborn disease. (Fig.7)[14] Snow's contribution was an early use of

Fig.7
Original map by John Snow showing the clusters of cholera cases in the London epidemic of 1854.

information design to help solve a world problem; Snow's map became a favourite of information design researchers.

However, Mark Monmonier (1991) demonstrates the possibility of a range of very different outcomes if Snow had chosen to aggregate his map by area instead of using dots to mark individual deaths. Different areas highlighted with an increasingly darker colour to indicate the number of deaths would appear different according to the placement of the area border. This shows that choosing the right parameter for the right cause is crucial in displaying information and failing to identify the right parameters (intentionally or not) can distort the (communication) outcome. (Fig.8)[15]

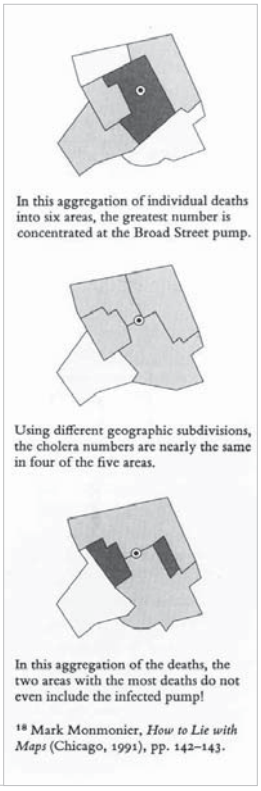


Fig.8
Monmonier demonstrates how different parameter influence outcomes.

The importance of using the right design features to aid comprehension

Another example exists within Tufte's repertoire: Tufte's (1997) redesign of a scientific numerical simulation that visualised a thunderstorm lasting two hours and twenty minutes emphasised the need for contextual accuracy and labelling in order to point to the important details of the visualisation. In his illustration, Tufte toned down the grid of the original animation as its stark contrast distracted from the dynamics of the cloud development. Reference information was also added. (Fig.9) Figure 9 illustrates the entire duration of the animation to provide contextual information and time. The two-dimensional cutting planes, in conjunction with the three-dimensional cloud and the quantitative scale at the bottom, provide multiple reference points and allow for comparison and clarification of the visualised data. Tufte's redesign manages to simplify the visuals of the animation while still keeping a level of realism the viewer can relate to (without sacrificing information in the process).[14]

2.2.2 Disaster Mapping

Large-scale maps do not offer the level of detail required to locate an area of importance (or possible danger) in a local context. Monmonier (1997, 67) suggests evacuation maps available in the Hawaii White Pages provide a good example of the importance of accessibility and consistency of messaging. The maps provide accurate local information about hazard zones, with clearly identified boundaries. They have been available in the Social Services section of the White Pages since 1991. (Fig.1) The White Pages are a common household item distributed and updated once a year at no cost, so this means wide accessibility and circulation of current printed information to most of the community. Although the maps allow for an overview of the safe zones, it is, however, unlikely they would be looked up in an emergency with limited time available.[16]

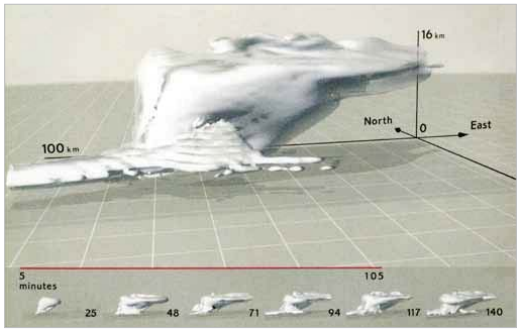


Fig.9
Screengrab of the E.Tufte's redesigned animation of a superstorm.

Additionally, Monmonier identifies Ute Dymon, as a cartographer focusing on the design and use of environmental maps who identified two types of maps: (I) risk maps, displaying areas of high risk for natural and technological hazards, and (II) response maps, describing evacuation routes, shelters, monitoring points and other spatial information useful immediately after a disaster. He states (1997, 294):

> *"Essential in emergency management, maps tailored to specific situations are equally valuable in emergency preparedness … By encouraging users to explore the effects of specific circumstances, interactive mapping promotes an understanding of risk that is difficult, if not impossible, through traditional, print-based cartography."*[16]

2.2.3 Interactive Information Design

Ralf Burmester et al (2010) states interactivity in design is founded on a two-way communication process (dialogue) between user and artefact. The interactive infographic invites the user to interact, to click and explore. Every click will be responded to with another bit of information. This dialogue develops in different levels of interactivity starting with clicking on a single button up to a high level of interaction, presenting the user the opportunity to modify the outcome of the information i.e. by changing parameters. Infographics become 'interactive' when they offer the user more information by active engagement.

If the underlying principles of information design can be adapted to interactive information design, how can they contribute to make the design effective?

Burmester (2010) identified a range of design guidelines to successfully implement interactivity into information design: A focus on usability (as common in web design), consistency, a clear layout, avoidance of cognitive overload and a structured navigation all aid in a successful dissemination of information content. The implementation of these features allows for different hierarchies, non-linear structures and diverse levels of displaying information as the user can decide where to navigate to, or how to explore the information deemed relevant.[17]

2.2.4 Neogeography/Social mapping

The introduction of web mapping like Google Maps and Google Earth allows for new possibilities in online cartography, especially in conjunction with a customisable application programming interface (API). It is up to the user to chose what information they want to access. Andreas Neumann (2007, 1262) states:

> *"The use of the web as a dissemination medium for maps can be regarded as a major advancement in cartography and opens many new opportunities, such as realtime maps, cheaper dissemination, more frequent and cheaper updates of data and software, personalized map content, distributed data sources and sharing of geographic information. It also provides many challenges*

due to technical restrictions (low display resolution and limited bandwidth, in particular with mobile computing devices, many of which are physically small, and use slow wireless Internet connections), copyright and security issues, reliability issues and technical complexity. While the first web maps were primarily static, today's web maps can be fully interactive and integrate multiple media. This means that both web mapping and web cartography also have to deal with interactivity, usability and multimedia issues."[18]

Advancements in digital cartography and the wide acceptance and accessibility of web mapping has allowed for the 'democratising' in the usage of maps. This 'neogeography' as defined by Turner (2006, 2) is about the people creating and using their own maps, on their own terms, by combining elements of an existing toolset.

> *"Neogeography is about sharing location information with friends and visitors, helping shape context, and conveying understanding through knowledge of place."*[19]

2.3 UI – Graphical User Interface

2.3.1 Definition of User Interface (UI)

In the relatively new field of designing for mobile devices, two companies – Apple and Microsoft – tried to maintain a common visual language and a consistency in the function of applications in order to avoid consumer confusion. In recent times, Apple focused on skeuomorphisms, which is an effort to imitate a real life item with the goal of getting the user to make a connection with a (often superseded) physical product and adapt their knowledge to the function of the application. One example is the calculator function on the iPhone, which has been designed to look very similar to Dieter Rams's and Dietrich Lubs's calculator from 1987. (Fig.10) At the same time Microsoft is trying to revitalise their Windows8 graphic user interface with a modernist undertone that focuses purely on function and design. The latest incarnation of their operation system aims to distinguish between the different program functions by different panels sporting a very reduced iconography, separated by bold colours.

Due to the limited real estate of the mobile phone's display area and its capability of displaying information, it is advisable to avoid skeuomorphisms and reduce the design to the essence of its function. As an example the technology norm for mobile devices, at this time, is the touchscreen, which allows for a multitude of touch gestures and offers a wider range of functions than any button or computer mouse can offer. However touch screens do not provide the user with the same physical feedback that a keyboard or a mouse button can. The same applies to visual references on stationary computers. While we have become accustomed to recognising changes in the appearance of the mouse arrow as an indication for a text field or another area of interaction, touchscreens do not offer this function. It appears to me that this leaves the User Interface (UI) designer with two options: (I) to decide on iconography that has become common knowledge (although limiting) and therefore should avoid misinterpretation, or (II) clearly indicate areas of interaction by utilising fundamental design principles like contrast, scale, colour, etc. and try to get the user to learn the functions by interaction and play.

This means that the UI designer has to adapt to the possibilities of mobile technology and should be encouraged to design with digital authenticity in mind. Design elaboration and visual metaphors are valid methods still commonly used in icon design. Decorating elements without obvious functions is a design feature that can skew or even dilute the message. An example is Apple's application iBooks, which displays a couple of pages on the right side of an ebook. It does not matter if the reader is on the first or on the last page of his book; this design does not display more or less pages allowing for an estimate of when the book finishes. It is not only a superfluous design feature; it is

Fig.10
On the left is the iphone application inspired by Ram's calculator.

misleading and confusing since the design elements do not add to the comprehension of either function or content.

Current design for touch screen enabled mobile devices does not indicate buttons by adding rounded corners or coloured bevels as is common for websites. Since the haptic feeling will always be the same of touching glass only, users have adapted to assume the interface design will either lead through the navigation or the interface in itself *is* the navigation. This understanding has resulted in the practice termed 'interaction design' which concentrates on making an experience feel natural without resorting to mimicking the devices of the real world. Interactivity and our perception of static information has changed with the rise of tablets and mobile phones as users often expect the whole surface to be interactive and are very quick in adapting to it. For example, I observed that when my friend's four-year-old son was confronted with an iPad, he not only was very fast in figuring out the functions of the device, but navigated, pushed, pinched and swiped through the whole range of available gestures to advance in the game he was playing.

In his seminal paper Digital Natives, Digital Immigrants (2001, 1), Mark Prenscy states that today's students have grown up with new technology and have:

> *"... spent their entire lives surrounded by and using computers, videogames, digital music players, video cams, cell phones, and all the other toys and tools of the digital age ... It is now clear that as a result of this ubiquitous environment and the sheer volume of their interaction with it, today's students think and process information fundamentally differently from their predecessors."*[20]

Psychology and states of design

In order to make a user interface design more adaptable and more appropriate to the displaying medium, the designer needs to cater for a range of systems that people are accustomed to. The notion of 'affect' is important in this situation. Affect is the state of either a negative or positive 'gut feeling'. The affective system lets the user make a quick judgemental decision – whether conscious or subconscious – if something is safe or dangerous, whether you find something attractive or unattractive, or whether you want to engage or not. (Norman, 2004, 11) Emotion is a consequent affect of experience. My friend's son was excited about playing with the iPad and although he didn't know what the game was about, the colours and music gave him the idea that it would be a great experience to play with it. His frustration about the limited gameplay resulted in him abandoning the experience; his emotional response to a failed promise.

Cognition was his response in recognising the iPad as a gaming device. In this case, affect, emotion and cognition are all complementing each other. Our affective system which includes the emotional system lets us make value judgements if something is good or bad, safe or unsafe, whereas cognition as part of this system lets us evaluate experiences and makes us learn and understand the things around us and assign meaning.

To elaborate on these systems and how they work on our consciousness, Norman (2004, 21) separates between three levels of processing: visceral, behavioral and reflective. The visceral level is the most

'primal'; at this level the user makes rapid judgements about a product – is it safe or dangerous, etc. This is the beginning of the affective process. For design and marketing it is the level to strive for as the user will react with these questions:

(I) What is it?

(II) What does it do?

(III) How much does it cost?

Visceral design works across cultures; it is inherent to all people. It is attractive to the designer, even if somewhat simple, and can be achieved by following the most basic design principles of composition, repetition, alignment and proximity.

Behavioural design is useful for any design that requires function, understandability and usability. On the behavioral level we act instinctively, by routine and on an unconscious level – for example, like driving a car, which after a learning phase turns into a repetitive task that does not require a lot of thinking.

The reflective level is the level of conscious thought that enables us to consider our actions, make conscious judgements and learn new concepts. Reflective design gives the designer the chance to introduce new theories and ideas and although it actively engages the user's thinking, it is subject to trends and fashion and can become dated very quickly. Design on the reflective level wants to attract by suggesting its use can raise the social status of the user.

To sum up, visceral design is about appearance, behavioural design is about the pleasure and effectiveness of use, and reflective design delivers self-image, personal satisfaction and memories. (Norman, 2004, 39)

This project aims to deliver its design on visceral and behavioural levels. Reflective design plays a minor role since reconsidering a warning and making a decision based on someone's personal gain would be counter-productive in an emergency. Everything we do has a cognitive and an affective component – cognitive to assign meaning and affective to assign value. Affect, both positive and negative is everywhere. This means that no matter where we are, what we experience or what we see, we will make a judgement call or decision.

A state of positive affect on one hand will open us up for a wider understanding of our situation since our mind is at ease. Someone in a relaxed and happy mood will be more likely to see the big picture, is more creative and will be able to overlook minor faults on a device. Negative affect on the other hand means, for example, that we associate unexpected loud sounds or great heights with danger. Even if we are at a safe distance from any potentially threatening situation, negative affect will raise our adrenalin levels, tense our muscles and force us to concentrate on the single reason we are finding ourselves at unease. (Norman, 2004, 26)

Design for emergencies

When people are anxious, they are more focused and will be less tolerant to design errors. For example, emergency doors in theatres are required to open outwards when pressure is applied since a person in an emergency will focus only upon escape. Highly anxious people are unlikely to focus on pulling a door to open, so when they reach the door, they push. If the door fails to open, the natural response is to push even harder. In order to make the design adherent to an emergency situation, the designer needs to make sure the information needed to complete a task is ready and continually at hand, legible and with an unambiguous and clear feedback about the operations the device is performing. (Norman, 2004, 28)[21]

In a distressing situation, it is not only the physiology of our bodies that is undergoing change; people's perception changes too and can even result in what scientists call 'tunnel-vision' where people become so focused that they may not be able to see what would otherwise be obvious alternatives due to a loss of peripheral vision. (Norman, 2004,28). This can even add up to experiencing multiple symptoms like accelerated heart rate, sweating, trembling and shaking, or feeling faint. (Nilsen & Bjelland, 2006, 7)

Nilsen and Bjelland (2006, 15) emphasise the need for guidelines when developing products or systems for use in stressful situations. Although stress responses from individuals will vary according to their ability to cope, it is common that their creative problem-solving skills are reduced. Accordingly, a distress situation affects most senses including cognition, speech, hearing, vision, and motor precision and control and consequently needs to be addressed in the design.[22]

Relevance to the design of a mobile tsunami education system

The tsunami education system that is the focus of this project relies on visual information. Interface designs that are complex and detailed in an 'idle' state must adapt to the user's rising stress levels in an emergency, and offer a simplified but congruent version of the information while maintaining their initial function. Following a tsunami warning, the application must still offer assistance in way-finding and communication with relatives and emergency response teams.

2.3.2 Designing the User Interface

Alan Cooper (1995, 4), a software designer and programmer regarded as the creator of Visual Basic and known for his writings on design methodology in interaction design, separated user interface design into three paradigms:
(I) the technology paradigm where the user needs to show an understanding of the software's function and underlying structure;

(II) the metaphor paradigm, which is focused on the transmission of an often-superseded representation of a technology, for example the headset of an old telephone to indicate the call function. Using visual metaphors has its disadvantages as there can be only a limited number to indicate a very specific function and metaphors usually fail at communicating more complex terms or functions;

(III) the idiomatic paradigm, which Cooper advocates most. Unlike the technology paradigm, in the idiomatic paradigm people do not need to understand what is seen in order to learn it. Scrollbars, tick boxes, radio buttons and pull-down menus do not require a deeper understanding of the underlying function in order to make them work. They are effective because they are easy to learn and memorise.[23]

To make functions more obvious, audio feedback can be used to increase the effectiveness of a user interface. The use of audio feedback has never been common, and today it is only used to indicate the start up of a computer or a function becoming unresponsive due to an input error. Edworthy (1996, 101) states that if an auditory signal serves as an alert in a warning context, it will become the feature that draws attention to a problem and provokes the user to look for further information. As such, an auditory warning may be useful to draw attention to the user, and shows the potential to disseminate the first information if the context has been learned by the user.[24]

Fig.11
The UI of the program AmpliTube 3 designed with its real world counterparts in mind.

2.3.3 UI History and Trends

In 1995 Cooper suggested that design for interface needs to adapt to trends in technology and so does the user. Mike Kruzeniski is principal designer at Microsoft and known for his contribution to Metro, a design language for mobile phones based on principles of classic Swiss graphic design. He advocates a reconsideration of established design principles common in print design practice, especially in regard to the recurring changes interaction designers are faced with today. Feedback from consumers indicates they would prefer to see 'less' design in their online experience. However, 'less design' has been proven to be a misnomer for 'good design'.

Good design is unobtrusive and tries to convey the information by reducing visual clutter and redundant components. Users' wish for 'less design' actually can be translated as wishing for a better, clearer and less ambiguous interface. Kruzeniski (2001, 1) quotes Paul Rand, an American graphic designer widely recognised for his contribution to modernist design as saying:

> *"The public is more familiar with bad design than good design. It is, in effect, conditioned to prefer bad design, because that is what it lives with. The new becomes threatening, the old reassuring."*[25]

In the early days of the web, interface designers decided that visual metaphors were needed as a reference to understand the function of the technology.[26] Visuals were focused on a hyper-realistic recreation of outdated gadgets with ergonomics, usability and cognition the driving forces. Interface design in those days converged around techniques for manipulating and organising content, symbolising our digital things. Kruzeniski summarises this as 'artifact as UI'. (Fig.11) (36)

After an initial 'incubation' phase that spanned the birth of the internet to the present-day, a change in design and user behaviour is now occurring. A whole generation of technology-enabled users have come of age at the same time as displaying devices, communication networks and computing power. Creating digital personas and lives rather than being the caretaker of our digital possessions (like pictures, games, files, etc.) is common. Instead of artifact as UI, the design changes to 'information as UI'. Content is represented as it exists, meaning the content *is* the interface. For the user, content is assumed to be interactive and for the designer, speed, usability and retention time are the primary concerns. The driving activity here is the accumulation of relevant information on objects, people, places and data.[25]

Kruzeniski's comparison of print design to user interface design is helpful to make a point but can be misleading due to his use of out of context terminology. His idea is not to compare two different technologies but rather to point out information and communication design principles that evolved by print practice, claiming that today's UI appearance has derived from the early days of computing and has not evolved as quickly as the user was adapting to emerging technology. A way to close this gap between UI appearance and emerging technology is elucidated by the likes of early information/ communication designers Otl Aicher, and later Paul Rand and Massimo Vignelli, who all advocate a modernist approach to information design. Hierarchy and grid, confident use of white space, reduction of redundant design elements, composition, a persistent focus on typography, proportion and rhythm and a universal iconography are fundamental to make information design work for interfaces.[26]

2.3.4 Gestures and Navigation

Interface design has reached the same transitional level as the technology-enabled generations of users. 'Digital Natives' are using the available hardware and software confidently, as well as the associated communication networks they have grown up with. They are also demonstrating an assertive approach to navigating interfaces by utilising a wide range of hand gestures. When learning to use a

new application on mobile mediums like touchscreen enabled tablet computers and mobile phones, this group relies especially on a mixture of kinesthetic and visual learning styles. They need to experience the functions in order to memorise them. So far, a wide range of navigation gestures have found their way into daily use and usually are the first to be utilised when trying to learn about the functions. Pinching the screen for zooming has become standard for all map applications and sideswiping to flip through content is an expected feature to navigate efficiently. Using short message service (SMS) to communicate is still an established, efficient and cost-effective way to get a point across. However, users and manufacturers alike have already come up with ways of reducing the cognitive load – typed acronyms spell out complete sentences, auto-correction helps by suggesting a range of words before they are typed and users themselves reduce effort in typing out a complete sentence without using any vowels. Additionally, speech recognition on mobile devices shows potential of becoming another aspect of navigating the device. Integrating this knowledge with context should further reduce the cognitive load in a distress situation. A combination of navigation gestures and pre-written statements that can be combined for more efficient communication should more effectively address the user needs during a developing disaster event.

2.3.5 UI Information Design

Following my research question on how information design can assist in tsunami education and preparedness, it was necessary to compare two different applications in publicising information design. Both are encompassed within the same framework and based on the same objectives of visualising complex information and allowing insight into the subject matter. The most challenging part of information design is appealing to the intended audience and convincing them to receive the intended message. Once the viewer is engaged, the design needs to communicate in a clear and coherent manner, making complex content comprehensible. Finally, the content needs to be memorable and in the case of this project, the users need to be able to recall and remember key areas in their geographic environment.

Recent findings suggest that an illustrative and visually appealing style can help maintain retention rates on recalling information. These considerations are context specific but pose an interesting argument for evaluating conservative approaches of visualising complex information as suggested by Scott Bateman, assistant professor at the University of Prince Edward Island. (Bateman et al, 2010)[27]

Lankow (2012, 34-36), a professional designer and author specialising on information graphics and visual content strategy, separates the field of information design into (I) one with explorative, and (II) one with narrative characteristics, with both having different applications. Academic research, science, business intelligence and data analysis rely on minimalist design consisting only of data forming elements to communicate information in a clear and concise manner. Contrasting this are publications, blogs, content marketing and sales materials that involve illustrative, design focused and engaging visuals seeking to appeal, inform and entertain the viewer.[28]

Edward Tufte (2001) has coined the term ‘chartjunk’ (redundant graphic elements that do not communicate any information) and uses it to describe the data-ink ratio to point out the number of elements needed in relation to the information they convey. Tufte advocates a conservative approach in visualising information and believes that unnecessary elements only distract the viewer and distort the information.[29]

In contrast Nigel Holmes, a British graphic designer known for his illustrative information design for the Time Magazine from 1978 to 1994, favours visualisations that not only present information but also explain concepts. Holmes prefers to use the term ‘explanation graphics’ for his designs as ‘information graphic’ is too vague to describe his narrative style of work. He includes a range of visual embellishments in order to draw the viewer’s eye and to assist in conveying a specific message and helping to make charts more memorable.[30]

While both approaches have merit, they should not be seen as strictly separate. Explorative and narrative elements can work next to each other and aid in the retention of the displayed material. The main focus of both approaches is generating a successful design – and what is considered a 'successful design' is very much different in science and research compared with those in general publishing. Consequently different industries and individuals should adhere to best practices in line with their communication goals and the application's possibilities.

Adapting the UI to the situation

Accordingly, the design approach in this project aims to be a merger between these different styles since the application of UI and information design serves varied purposes in different situations.

In the 'neutral' state of the application, the user will have the opportunity to explore functions and familiarise themselves with available options. This readily accessible information design aims to engage the user and educate about local terrain, escape routes and inundation zones as well as giving insight into information about, for example, prevalent knowledge like tsunami types, warnings and preparations. At this stage, this visceral design will be prioritised in the order of appeal, comprehension and finally, retention.

The second 'warning' state will follow principles of behavioural design with function, understandability and usability as priorities in the foreground. In a real emergency, the user is in an emotional state of negative affect, so the displayed information design will change its appearance and order of priority to comprehension, retention and appeal. Appeal is less important at this state, but the information will always be readily available and the user can revisit and retrieve it as needed.

Visual Interlude:

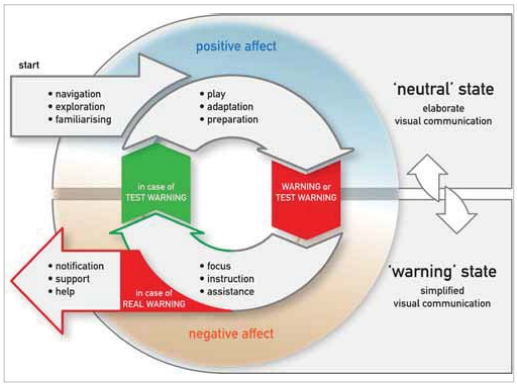


Fig.12
The continuum of experience:
This illustration explains the education model and how design adapts to the situation.

The above model visualises the different stages of the application:

At first, the user will explore the navigation and different functions and become familiar with the interface. The next stage concentrates on experience, interaction and play with the aim to educate and prepare. Both of these initial stages are under the notion of positive affect.

A tsunami warning (or during a test run initiated by the user) will change the design from complex and elaborate to straightforward and unambiguous. Under the notion of negative affect, the user will focus on escape and the design can assist and instruct. In a real emergency it will be possible to notify predetermined groups and emergency services and after a test run the user will have learned how to utilise the application in a real tsunami situation and can later return to the preparation function.

Sample a) Design change from 'neutral' to 'warning'

The left display on this page shows the application in one of the play states. The user can select different parameters to simulate a tsunami in Wellington harbour and south coast. After choosing the depth and magnitude of an earthquake, the application allows the user to navigate a birds-eye view camera through Wellington's inundation zone.

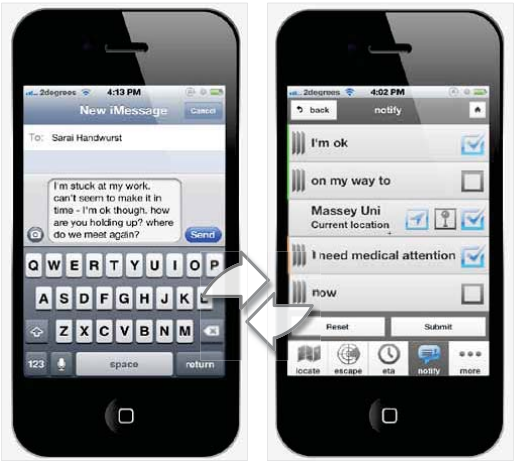
The right display is a simplified version of the same type of information. It offers a clear and quick assessment of a situation, independent from location. By offering a unambiguous indicator to advance, the user will be able to access all necessary information in quick succession.

Sample b) Design change from 'neutral' to 'warning'

The left display shows an inundation map that allows the planning of individual escape routes. The map can be zoomed in to clearly identify the area and important landmarks. Different levels of threat are shown as well as main escape routes.

The right display shows a compass pointing to the closest safe elevation. By real-time assessment of the mobile phone position it offers an emergency way-finding system and displays the areas to avoid. Different colours ranging from red to green indicate elevation and level of safety while the colour in the middle of the compass shows the current safety level.

Sample c) Design change from 'neutral' to 'warning'



The left display shows the current interface for SMS messaging. The keyboard contains most of the characters of a standard computer keyboard and allows for a whole range of communication. Although familiar to most users, the keys can be hard to use in a distress situation due to the small size. Additionally, having to use all characters to type out a message could be time consuming and ineffective when time is scarce and people are distressed.

The right display gives the user the opportunity to combine and send pre-written emergency messages addressing the most important information needed at this time. Additionally, the application sends this message immediately to predetermined groups and emergency services. Colour indicating the level of urgency for the user and recipient can reduce cognitive load, and the location data of the phone can be mapped, analysed and reacted upon by emergency services.

Sample d) Design change from 'neutral' to 'warning'

The left display shows the current UI of the phone's timer application. It is purely functional and displays hours, minutes and seconds in a clear and concise manner. The font used is Helvetica Neue. However, to access different functions, the user will have to swap between the four options on the bottom of the display.

The display on the right shows all the necessary information on a single screen. At top is the current time, below that is the estimated tsunami arrival time. The estimated time increases in contrast and size to better visualise the urgency of the approaching tsunami. An orange progress bar gives an additional but unobtrusive visual indication of the time remaining. The font used (DIN Mittelschrift) has been developed with high legibility in mind and is used for road signage requiring quick comprehension.

3.0

3.1 Data Collection and Evaluation

3.1.1 Establishing the Field of Research

Tsunami danger is real and design, education and preparation can help build a resilient community. The 2011 Tohoku earthquake and resulting tsunami emphasised the importance of 'Tsunami Tendenko', a Japanese teaching practice prioritising individual action and self-preservation, but a concept still perceived odious in Japanese culture. This teaching can loosely be translated as: "go uphill independently at the time of tsunami caring only for your own safety, not thinking of anyone else, even your family."[30]

The Tendenko teaching programme is believed to have saved many lives in Kamaishi, Imate prefecture, because people knew how to respond and to act without hesitation. Students of Tendenko have obviously developed self-efficacy and realised it was better to stop looking for family members who were geographically far from each other at the time of the tsunami.[31] The concept of Tendenko offered a good starting point in understanding how disaster education can raise people's trust in their own ability to act and validated the importance of being well-prepared.

Webb (2005) compiled a vast amount of research material on New Zealand's level of tsunami preparedness and as a result, developed a deeper insight into the human character and psyche. Webb identified that critical awareness and risk perception of individuals are an important preliminary factors for disaster preparedness. (82) When respondents were asked about what makes up the local tsunami warning system over two thirds admitted they didn't know or don't know if there was one in place at all. Despite this, an average of 87% of those questioned knew to move inland when a tsunami message was issued. In terms of information availability, one third had seen or received information about tsunami and less than 11% indicated that they had never asked for any information. These numbers suggest public education to be the key component for successful implementation of warning systems, although the mere existence of a system does not necessarily mean people understand how to respond to a warning.

In terms of risk perception, it has been shown that there is a great disparity between an objective analysis of risk potential, and an individual's assessment of risk, and how it translates into action. Response to risk and its understanding is often founded on, and linked to, a mix of psychological, social, cultural, institutional and political processes. (Burns et al.,1993; Sjöberg, 2000)[32,33] Although people may acknowledge objective risks in their community, they tend to attribute these negative implications to others rather than themselves. Weinstein & Klein (1996) identified that unrealistic optimism and a false sense of security can be seen when people underestimate the risk for themselves and overestimate the risk to others. It is hard to break this habit, but can be positively altered when confronted with samples of precautions successfully undertaken by other people.[34]

Reports like this can change the attitude and fatalism people feel when confronted with initial media coverage focused on the devastating effects of tsunamis. It is quite a daunting task to motivate people to prepare if they do not perceive a risk as consistent or obvious. Paton (2003) identified that without consideration of risk level, action will be inhibited and limited if people identify the risk as overwhelming (low outcome expectancy), if they see themselves as incapable to act (low self efficacy) or are complacent (low action coping). The assessment of a potential risk may not trigger action to prepare if people cannot find the resources they need for implementation (low response efficacy), if they don't feel the responsibility lies with them (low perceived responsibility), if they mistrust information sources or simply ignore the looming nature of hazards.[35]

To achieve a higher rate of preparedness, this project aims to address the awareness of tsunami as a catastrophic event and work towards enhancing self-efficacy and competency to act accordingly. The combination of public education, local relevance, ownership,

involvement and psychological intervention by design and mobile technology creates an effective mixture of warning, response and understanding capacity.

3.1.2 On Methods

I have approached the topic of tsunami warning systems and communications using a range of research methods: Field trips, reports, interviews and workshops provided valuable insight in the status of today's science on tsunamis and technology. This background research formed sufficient overview to start my design process.

The CDEM's 2010 tsunami exercise Tangaroa final report highlights shortcomings and recommendations for improvement in tsunami preparedness and evacuation. Although successful in simulating evacuation techniques for stakeholders, CDEM reports it had been the right decision to not let the public participate, as media exposure of the Tohoko earthquake in Japan was still fresh in people's minds and would have meant that the public had a higher level of awareness than in a normal situation. "An additional campaign would have risked 'tsunami fatique'."(36) The report also states that

> *"Hazard education is improving off the back of the real events, but some improvements (such as the threat level indicators on threat level maps) require further development and education." (37)*

In written correspondence, Dr Jörn Behrens, (Professor for Numerical Methods in Geosciences at Klima Campus, University of Hamburg) revealed insight into some important preliminary requirements to consider before I started designing. Behrens pointed out that the possible damage of communication infrastructure in a large-scale disaster may have to be considered when aiming for a dependent (mobile) warning system. This issue was raised repeatedly at each of the Master of Design critiques. I responded to this challenge by developing this project as an 'ideal' scenario because the technical implications were not the prime concern of my research. Behrens supported my initial findings of tsunami science not showing enough emphasis on visual communication design and helped my understanding by mentioning the difficulty of horizontal evacuation . As a result he suggested the possible inclusion of vertical evacuation (higher levels in close-by buildings) as it is an important aspect influencing decisions in disaster management. (J. Behrens, personal communication, February 4, 2011).

Dr Stefan Reese (NIWA) revealed in an interview that New Zealand government agencies rely on the data for approximately 300 pre-rendered scenarios that will be made publicly available in case of a real tsunami.[2] Calculating the risk in real time is impossible given today's state of technology. Too many parameters such as tides, travel times, cause and effect of the initial earthquake, topography and ocean currents, will influence the outcome and make estimating impacts imprecise and ethically questionable. The technology already exists as demonstrated in the software programs Gerris Flowsolver (developed by NIWA) and Anuga (developed by the Australian Government), both of which are used, albeit rather slowly, to make tsunami simulations and calculate water movements on coastlines.

Edworthy and Adams (1996) research in Warning Design is backed by a wide range of experiments in legibility and comprehension, typography, white space and placement of the actual design. Although their research was conducted in the very early days of the internet and constant access to information was not part of daily life, it remains relevant. Edworthy and Adams were measuring reaction times and perception as well as comparing the effectiveness of colour and hierarchy in warning design. (29) Warnings that are always present (like labels on prescriptive medicine) run the danger of being overseen; people become used to the warning signs and don't see the danger associated or understand their relevance under certain conditions. Furthermore, Edworthy and Adams (1995) showed that written warnings will be perceived as more urgent with increasing text size, and an adaption of this theory will be a major feature of the risk application. (31)

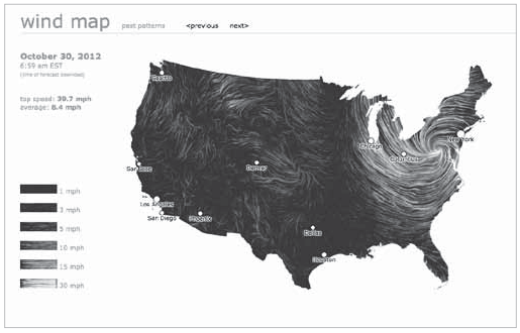


Fig.13
Hint.Fm's animated windmap on 30th October 2012. Although not usable for navigation, the design of this map allows for a good estimate on windspeed and dimension of Hurricane Sandy.

3.1.3 Technological Prospects

More research into technology revealed a wide range of approaches in how digital maps and information design can aid in visualising a complex subject. Contrary to printed material, digital maps can be designed with features inherent to web design practice like interactivity and flexibility of updates. The wind map projects of the information design studio Hint.Fm (www.hint.fm) is harnessing data from the National Digital Forecast Database and utilise Javascript to illustrate windspeeds in real time on a digital map. (Fig.13) HTML5 in combination with WebGL by Google Inc. is experimental open-source code available on their website (www.chromeexperiments.com) and Evan Wallace managed to realistically simulate water movements with this piece of software. It is possible to interactively play with this simulation in real-time and in any supporting web browser. This is a remarkable technological advancement considering the slow render times of classic 3D programs and it is likely that these will soon find a translation to mobile devices.

Another experiment utilising WebGL visualises global small arms trade import and export by country. A very engaging design, it allows the user to choose from a range of parameters to make up their own map and concentrate on an area of interest. Enabling the user to limit or expand on their choices of visualised data reduces cognitive overload and gains higher attention by interactive engagement.

Noteworthy too is the interactive information design developed by the American magazine publication Popular Science. Their 'Quaketracker' for mobile device visualises the history of earthquakes along two timelines. Using a map of the United States as canvas, one can, for example, display recent earthquakes or see the biggest earthquakes in historical context. Tilting the map by gesture navigation allows for a closer look at how deep the earthquakes occurred; the magnitude is illustrated by different sized shockwaves – the bigger the 'bubble' the higher the magnitude. Although the application does a good job in localising hot spots of seismic activity, it fails to go beyond 'infotainment', as it only displays constant looping static data.

Acknowledging these contemporary technological opportunities, it is likely the near future will give us the option to display current and flexible data on a three-dimensional map and allow for personalised, user-centred design. This project did anticipate some of these future design technology developments and has been prototyped with this in mind.

3.2 Design-led Research

3.2.1 A Design Proposal

After evaluating the existing tsunami education methodologies, I found it unnecessary or even detrimental to dismiss any established systems and collateral. However, I still felt inclined to improve on what is

available and use mobile technology's inherent advantage of location access.

Inundation maps downloadable as PDF available from the internet can be only as accurate as the scale of the map, meaning trying to cover a lot of ground will come at the cost of less detail. The blue indicator lines painted across the street in Island Bay are constant reminders, but also static and inaccurate as they are only indicative of the worst case scenario. Riskscape, which is openly available software developed for science purposes, evaluates cost and damage to infrastructure, but does not offer advice on tsunami mitigation, nor can it be accessed by the average person unless explicitly looking for it.

The fact that most of this educational material is either hard to access or provides limited information must, one would assume, make it harder for people to care and hence perhaps lead to lethargy and complacency.

In terms of distribution and access, a marketing research commissioned by Google.Inc in 2012 and conducted by Ipsos Media Ct found that 44% of New Zealand's population are using smart phones and becoming increasingly reliant on these devices. This survey also found that 59% of users accessed the internet on their phones every day.(10) The study claims that smart phones have changed user behaviour and the way users navigate. They summarized by stating that 80% of users now look up local information on their mobile phone with 88% taking action as a result.(22) These findings highlight the fact that mobile smart phone usage is an accepted mode of accessing time and location independent information and its use is increasing. (11)[36] While mobile technology is presenting unique possibilities to disseminate news and contextualised information to the individual user, it is also possible to locate mobile phones by means of GPS and mapping software.

The inherent technology of mobile devices offers a vast range of opportunities in disaster education and warning. Gyroscope, global positioning system (GPS), accelerometer, camera, time of day, personal preferences, accessibility and design with sympathy to context, are all evolutionary steps that make the 'smartphone' more efficient for quick access to news and guidance. These devices come with their own human interaction characteristics. Such characteristics need to be incorporated into any subsequent design.

Keeping these technical possibilities in mind, I figured the interaction and graphic design prospects need to adhere to a set of rules that aim at enabling the user to quickly comprehend the information presented, and then react accordingly. The visual communication needs to be simplified and reduced to the most important features in an emergency situation and this user-centred design will be influenced by the limiting capabilities of people in distress situations. To eliminate the misinterpretation of vital visual instructions of the user interface, the colour palette of non-interactive or negligible elements should be reduced to a minimum allowing for a high contrast when colour is needed to draw the attention of the user. The legibility of the design can benefit from scale, contrast and proximity. It is important to reduce the information count for the (already focused) user to a minimum and make it as unambiguous as possible.

Typography plays a major role in the correct interpretation of information supplied, and needs to be chosen with consideration of these design constraints and with a high grade of legibility in mind. There are fonts that have been designed to be read in a state of high anxiety and/or behavioral processing of the environment. For example, Henry Dreyfuss (1959, 41), industrial designer in the 1930's and 40's focused on common sense and a scientific approach in design and writes that all characters need to be read vertically with avoidance of vertical words, and that sans serif fonts (e.g. Futura medium) are most clearly legible. The stroke/height ratio should be considered as well as an increase of font size for 'critical' text displayed on a moving item. (Fig.14)[37]

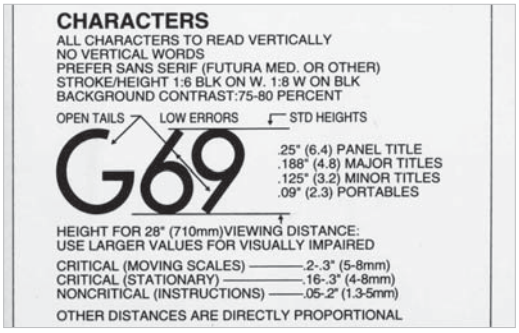


Fig.14
Dreyfuss's considerations for typography on technical equipment.

3.2.2 Technology Development

In my initial research I considered how the publicly available Google Earth facility could be utilised as the prime feature for indicating safe zones and hazard zones. The project developed via several iterations. For example, three-dimensional features, fly overs, HTML5 supported videos utilising Google's streetview API (Application Programming Interface) and the recent start of digital seafloor mapping all seemed to point in the right direction. Although promising, I quickly decided that I did not want to restrict my design to guidelines established by a third party company due to their inflexible modelling and generalised focus having no priority on 'what if' scenarios rather than visualising the current state of the planet. This led me to search for other solutions similar to the independently developed simulation programs (Gerris Flowsolver and ANUGA), which calculate impacts and water movements on a model coastline. These examples can accurately display the inundation of a coastline and translate scientific data into easily understandable and engaging visuals. However, although freely available, both these software packages require great knowledge of coding systems, and display results only suited to scientific modelling.

Following this, I decided to research the opposite spectrum: I attended a course in simulating fluid dynamics with Realflow and HYBRIDO, software used in the film industry to reproduce realistic looking waves and fluids. Learning the program turned out to be quite a challenge and although the first drafts showed encouraging results, I stopped the experiments when realising the required render times, high technical demands of the program and the limitations of the screen real-estate formats it can handle. Realflow has been developed for the film and advertising industry, and while it shows impressive cinematic special effects, I concluded it was not suitable for this project. Eventually I concluded that the programs Maya and Unity 3D offered more technical flexibility and allowed for a viable approach. These software programs have become the foundations of the 3D interactive part. (Fig.15,16)

At this point in my project, I explored JQuery mobile as the primary software to use for the interactive user interface. JQuery mobile offers an established design library in use on most mobile applications, so it became not only the obvious choice for ease of programming but also its visuals and iconography are already known and accepted by people used to navigate mobile applications.

Before committing to the development, I drafted a simulation of content and user experience in Flash catalyst, a program specifically created to enable designers with limited coding experience to plan content, hierarchy and transitions for interactive projects. This draft played a major role in explaining and testing the concept on multiple users with different backgrounds. (Fig.17)

Fig.15
Particle fluid simulation in Realflow2012 Hybrido.

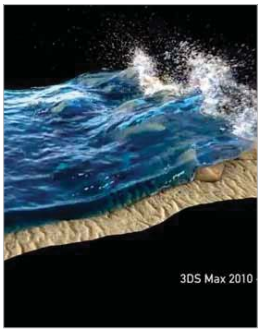
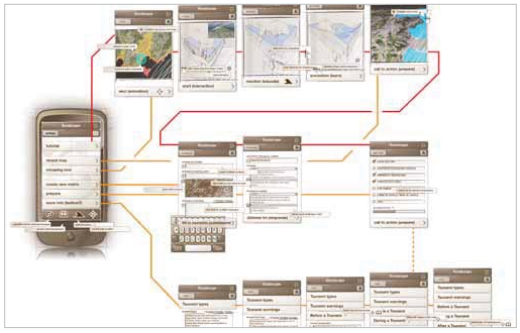


Fig.16
Sample of a possible outcome. The software turned out to be unusable for this project's purpose.

Fig.17
Wireframe displaying the relevant connections and areas of the prototype.
The top third is for infotainment, the middle preparation and the bottom education.



3.2.3 Visual Communication Development

My early experience was that available information on tsunamis was often too complex for users. For example, tsunami warnings, and maps indicating travel times required quite a bit of deciphering. The use of colours to illustrate wave intensity, and maps scaled to make out whole continents, resulted in messages that were unclear to users. My goal for the visual communication was to simplify and make information accessible and relevant to the user's need. (Fig.18)

The Museum of New Zealand Te Papa Tongawera has a reputation of educating its audience by means of interactive displays and installations. These displays appear to be well received by the public and add to the learning outcome by offering a wide level of engagement through play. On a field trip I observed a group of children, trying to interact with a large backlit map of New Zealand displayed on the floor after they had experienced the same with another installation. They were pointing out their home and reacting to random lights flashing between the floor tiles. These were a stimuli for them to jump up and down trying to switch them on or off. I concluded that the New Zealand map has a very distinctive shape learned at a very young age and further, that these children expected interactivity when the object appeared like a game. (Fig.19)

Following this, my task was trying to reduce the cognitive load and since local communities seemed to easily recognise their coastline, I tried to incorporate the map legend in the design. Inspired by Tufte's redesign of a superstorm, I created a simplified three-dimensional map that displayed distance and height in blocks. Testing it, people were able to recognise Wellington's Miramar Peninsula, but all of them preferred trying to locate their home rather than calculating distances. Although the concept was interesting to start with, people could not see themselves using a response map and were asking for more insight from a risk map. (Fig.20)

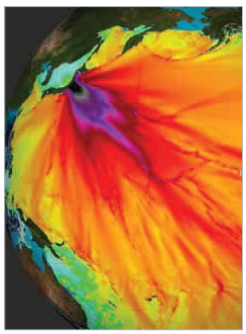
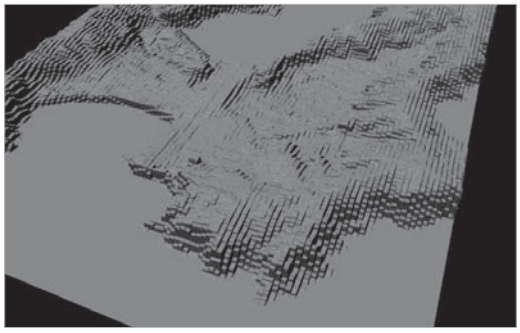


Fig.18
The 2011 Japan tsunami's wave height visualised as heatmap.

Fig.19
Illuminated map showing a satellite view of New Zealand in TePapa.

Fig.20
First draft of a reduced topographical riskmap visualising part of Wellington's coast line and height in scaled blocks.



At this stage I was concentrating only on the educational part as technological limitations in tsunami prediction and inherent ethical issues would not allow me to combine education and actual warning. However, after another review I decided to focus on a 'continuum of experience' (meaning different stages for exploration keep the momentum of the user's interest) and keep the conceptual nature of this project in mind. I created a wireframe and stationary working prototype to use in presentations and workshops. The design was intentionally left simple with the intention to get different audiences to concentrate on content, hierarchy and functionality rather than eye-catching aesthetics.

I tested the prototype on two very different audiences. First, a group of scientists in a workshop at the 6th Australasian Natural Hazards Conference in Christchurch on 24th August 2012 where I gave brief introduction to information design followed by a presentation of the concept of my risk application. The following workshop was based on Stappers (researcher at Delft University of Technology focusing on co-creation) and Sanders (2005, 5), theory of 'Contextmapping', a concept of design research in a group requiring preparation, sensitisation, sessions, analysis and communication.[37] Since this audience of scientists and risk managers expected a presentation rather than being part of the solution, context mapping did not work out as intended due to time restrictions and them missing relevant background information. Resorting to Rachel Hinman's (Senior Research Scientist at the Nokia Research Center in Palo Alto, California) concept of mobile prototyping proved to not work as intended either, but left me with valuable insight in how disaster mitigation experts react to new concepts in their field of expertise. The overall feedback of the workshop and the concept was positive and many agreed that disseminating warning messages more effectively on mobile devices is an important step to future proof disaster risk reduction. Although these scientists could not add value to visual communication, they gave excellent insights and contribution to the content like reaction times, the need for reconfirmation and other aspects of evacuation practices. (Fig.21)

Fig.21
The participants of the workshop discussing mobile strategies.

Fig.22
Mobile warning system prototypes drafted by graphic design students.

The second workshop occurred with a class of nine design students (aged 19 to 24), and was carried out using the same presentations mentioned above but in a different order to avoid preconditioning. After the introduction but before presenting the prototype, the students were asked to draw their vision of a mobile warning system on cards shaped like mobile phones (i.e. Rachel Hinman's mobile protoyping).[39] Students were required not only to draw the first screen but also what they imagined a warning application should include. The students had to take into account the mobile context, so they were asked to:

a) design for partial attention and interruption

b) reduce cognitive load and opportunity cost

c) consider non-stationary technological traits or opportunities, like gyroscope, GPS, accelerometer, camera, time, personal preferences, speech recognition, etc.

The outcome of this workshop confirmed that the inclusion of maps showing the local area was ideal. Warnings are needed to be displayed with bright colours and/or blinking design elements.

The overall outcome of both workshops and a later Master of Design critique confirmed my research was reaching the target audience.

An older demographic of 'digital immigrants' accepts and adapts to new technology; they expect accurate and goal-orientated information. Design is secondary as long as the communication is efficient and unambiguous.

The younger audience of 'digital natives' expected interactivity, engagement and an appealing navigation. Aesthetics were more important than the accuracy of the information displayed. (Fig.22)

A fourth Master of Design critique provided the last opportunity to reconsider design decisions and the feedback, and led me to consider a more subtle and straightforward approach. The visual communication can be playful and more complex at the education part but will need to adapt to external circumstances and recognise and use pre-learned interfaces . At this stage Kruzeniski's claims became quite influential and led to the inclusion of fundamental design principles and an awareness of how they aid in the comprehension and retention.

4.0

This exegesis outlines how interactive information design can enhance and deepen a learning experience in tsunami awareness for coastal communities.

In this design research project, gathering data and scientific evidence provided the necessary foundation to combine different approaches of visual communication with technology in order to cater for a wide range of learning styles and demographics operating amongst the anticipated primary user groups.

In most key areas of the Hyogo Framework[7] (apart from governance) mobile technology can play a significant role in reaching individual people in danger, but can also present a life-line for disaster victims by enabling them to communicate. Disaster education in New Zealand is of a very high standard but lacks user involvement and generalises its audience. Local relevance and ownership turn out to be the key ingredients towards making a message permanent and enabling communities to gather and plan for an emergency situation.

In an emergency situation, disseminating accurate and up-to-date information can mean the difference between free or blocked escape routes, efficient or wasted use of resources, and a calm or panicked community. The information provided by this design would be of value to both the general public and emergency response teams.

Research in disaster education, information design, user interface design and its perception, as well as mobile technology and user behaviour, led to prototyping an effective amalgamation of a tsunami education and warning system. The merger of these two different functions is beneficial to the user as it provides not only a clear visual interpretation of theory on the individual's terms but also encourages users to practise and understand the interface design. This should make it familiar and accessible in an emergency situation. The concept provides an engaging learning experience utilising touchscreen functionality and interactivity, but also provides areas for planning evacuation routes, post-disaster communication and tsunami mitigation.

When placed in a local context (using the Greater Wellington Region as case study), this mobile application enables the user to localise the personal impact of a tsunami by utilising interactive digital maps. It allows for ownership and involvement, and provides disaster response teams an additional platform for quick aggregation of individuals' location data. In addition, it can deliver relevant updates to these same sites.

In this design, user experience focuses primarily on the educational part with the notion to test a warning message as it would appear in a real scenario. This facet adds to the learning experience as it familiarises the operator with the user interface. Separating these two options of application functions led to new questions on the treatment of visual communication design and perception.

4.1 The Future of this Project – What's Next?

Hypothetically, this application has the potential to work on various levels. However, ethical issues will present the most obvious obstacle (i.e. how can this application cater for disabled persons? Could

children mistake it for a game? How can people of another culture benefit from it and how will its visual language be perceived?) and we have to rely on the user to not solely trust only one source of information. No tsunami warning system is without faults, especially when calculating risk and possible impacts and at this stage of technology, no computer system is capable of accurately predicting inundation zones as there are just too many parameters changing the outcome. In the near future and with more knowledge of seafloor topography, currents and seismic activity, I anticipate that we may be able to narrow down error margins and be more accurate and timely in our predictions and communication.

In a perfect world this application should additionally provide for people with disabilities, for the less technologically 'savvy', for children and others. Modularity of the application suggests people living in safe areas could modify the application to suit their individual needs, for example, as a teaching tool that visualises the history of tsunami in New Zealand.

For the future, a viable and useful approach could be the implementation of neo-geography that consists of the real-time collection, mapping and visualising of data sent by the user to pinpoint a victim's location and status. Evidence of this potential has been revealed in the initial concept of 'crowd-mapping' started when the website 'Ushahidi' developed a map to report and visualise reports of post-election violence in Kenya at the beginning of 2008. The original website has since developed into a non-profit technology company specialising in open source software for information collection and interactive mapping.[40]

Further development of this mobile application with a realistic ambition to commercialisation could lead to a tsunami simulator for use as an on-site training device for disaster response teams. Disaster response and management coordinated by civil defence organisations could be provided with a visual aid to assist coordination efforts.

A promising concept and hopefully part of my future research could be supported by upcoming advancements in technology and user interface design. At this stage, any input devices and touchscreens are operated by manual tactile interaction, but especially on mobile devices, we have the possibility to utilise already existing components or can develop new features reacting in the background to different stress levels. A front-faced camera could measure our eye movement, touchscreens could sense a rise in body heat or increased sweating, accelerometers and gyroscopes a tremble in our hands or body movements. By interpreting these signals, a mobile touchscreen device could be used for medical purposes as a diagnostic and treatment contrivance handing out guidance straight to the patient. Video games utilising the same prospective technology could help children overcome their fear of medical instruments required for diagnosis.

In conclusion, this design-led research project highlights the challenges rapid changes in technology bring and how established principles of visual communication are still building the foundation of a language and culture independent comprehension. However, our modes of absorbing information have changed; and constant access to information and connectivity asks for a new approach in disseminating messages. While developing this project I clearly recognised the potential for further research and more than once I had the feeling of only scratching the surface of a very interesting and important field of technology and design.

Without doubt, most articles, books and academic papers require consistency and do not need to be updated at the same rate as transient and ephemeral news coverage. As we move away from the classic model of reading, absorbing and memorising information, we now demand first-hand insights, background information and constant updating of information. Contemporary information gathering consists of responding to faster, reactive and fluent coverage and has become a process rather than mere consumption. Adapting to these principles can create the continuum of experience this project requires to enable communities to communicate efficiently and help building tsunami awareness and resilience.

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Fig.3 Wiki commons.

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Fig.7 Wiki commons.

Fig.8 Monmonier M. Retrieved from: Tufte, E. (1997).
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