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An Experimental Study on the Use of Sound, as Attention Grabber, in Map Animations

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Anna Bellika Kjæmpenes

An Experimental Study on the Use of Sound, as Attention Grabber, in Map Animations

BACKGROUND

The use of sound in geographic visualization is often discussed in literature, but the effect sound has on the users' perception of information is rarely studied. Limitations of map animations is no longer set by technology, but by the cognitive limit of the human brain. Adding sound in addition to visual variables, making the visualization multimodal, may raise this cognitive limit.

TASK DESCRIPTION

The goal of this thesis is to test and verify the effect of sound, as an attention grabber, in map animations. To do so, a map animation which includes sound will be created. Furthermore, a web-experiment will be designed and executed to test the effect, and the results will be statistically analysed.

Specific tasks:

- Study related literature and get insights into relevant technology and related work.
- Create a map animation, where sound plays a role as an attention grabber.
- Plan and create a web-experiment which test the effect of sound in map animations.
- Statistical analysis of the results of the web-experiment.

ADMINISTRATIVE/GUIDANCE

The work on the Master Thesis starts on February 3rd, 2020.

The thesis report as described above shall be submitted digitally in INSPERA at the latest at June 29th, 2020.

Supervisors at NTNU and professor in charge:
Terje Midtbø

Trondheim, February, 2020

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Abstract

The very first map animations were drawn by hand which was very time consuming. Ever since then, the technological evolution have presented unlimited possibilities for designing map animations. It is no longer the technology that sets the limit for what can be presented in a map animation, it is the cognitive capacity of the human brain. An often discussed theme in literature, but sparsely studied, is enhancing the effectiveness of map animation by applying sound variables. Results from cognitive research on multimedia strongly implies that adding sound, and making an animation multimodal, will increase the working memory capacity. However, this is yet to be verified for map animations. Therefore, this thesis is an attempt to verify or discard the effect of sound variables, as attention grabbers, in map animations. A web-experiment was designed and conducted using a map animation of significant earthquakes worldwide as stimuli. Sound was applied to the map animation, paired with a visual variable and functioning as an attention grabber for earthquakes of a specific category. The results of the experiment were not sufficient to verify that sound variables enhance the effectiveness of map animation. The conclusion is that the design of both the map animation and the experiment was not appropriate and should be improved. There were however some interesting results that implies that the use of sound increases the performance of the participants in terms of correct answers. The groups that saw the animation with sound had a higher percentage of correct answers on most of the questions regarding earthquakes of the specific category connected with the sound variable. On the other hand, some of the results indicate that the use of sound needs to be considered carefully. If applied incorrectly, the sound will draw attention away from other elements in the animation and increase the cognitive load. Despite the inconclusive results, this study provided some interesting results and the subject should definitely be explored further.

Keywords: Sonification, Multimodality, Map Animation, Experimental Study, web-experiment

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Sammendrag

De aller første kartanimasjonene ble laget for hånd, noe som er veldig tidkrevende. Siden den gang har teknologien utviklet seg og mulighetene for å designe kartanimasjoner er ubegrensede. Det er ikke lenger teknologien som setter en stopper for hva som kan presenteres, det er menneskets kognitive kapasitet. Et ofte diskutert tema i litteraturen, men sjeldent studert, er bruk av lydvariabler for å øke effektiviteten av kartanimasjoner. Resultater fra forskning innen kognitive teorier og multimedia læring antyder at multimodale animasjoner, animasjoner som benytter både visuelle variabler og lydvariabler til å presentere informasjon, vil øke kapasiteten til arbeidshukommelsen. Dette er imidlertid ikke bekreftet for kartanimasjoner. På bakgrunn av dette er denne masteroppgaven et forsøk på å verifisere effekten av å benytte lydvariabler som oppmerksomhetsfangere i kartanimasjoner. Et nettbasert eksperiment ble designet og gjennomført, der stimuli var en kartanimasjon av signifikante jordskjelv over hele verden. Lydvariabelen ble anvendt sammen med en visuell variabel, for å trekke brukerens oppmerksomhet til jordskjelv av en spesifikk kategori. Resultatene av eksperimentet var ikke tilstrekkelig til å verifisere at lydvariabler kan benyttes til å forbedre kartanimasjoner. Konklusjonen er at utformingen av både kartanimasjonen og eksperimentet ikke var tilstrekkelig. Det var imidlertid noen interessante resultater som impliserer at bruken av lyd økte prestasjonen til deltakerne på spørsmål om jordskjelv av den spesifikke kategorien knyttet til lydvariabelen. Deltagerne som så animasjonen med lyd, hadde en høyere prosentandel riktige svar på de fleste av disse spørsmålene. På den andre siden, er det resultater som presiserer viktigheten av å være forsiktig med bruken av lydvariabler. Dersom lydvariabler ikke blir benyttet på riktig måte vil det trekke oppmerksomhet bort fra andre elementer i animasjonen og øke den kognitive belastningen. Til tross for at denne studien ikke var tilstrekkelig for å konkludere med at lyd øker effektiviteten av kartanimasjoner var det flere interessante resultater. Temaet bør definitive utforskers nærmere.

Nøkkelord: sonification, multimodalitet, kartanimasjon, ekperimentelt studie, web-eksperiment.

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Preface

This master thesis was written for the Department of Civil and Environmental Engineering at the Norwegian University of Science and Technology (NTNU) in Trondheim, Norway. The thesis is the final part of the study program Engineering and ICT, with specialization geomatics. The work for this master thesis was conducted in the spring of 2020, which was a period for the history books given the corona virus situation. The situation required some readjustments, and I am thankful that this thesis was possible to conduct from my home office.

I would like to thank my supervisor Terje Midtbø for valuable feedback, guidance and help during the writing of the master thesis. I would also like to thank GeoForum for distributing the experimental test, and all participants for taking the time to participate in the experiment and give feedback. My family and friends also deserve a big thank you for their support and input, and a special thanks to Tova Kjæmpenes and Wenche Kjæmpenes for the help finishing the thesis. Lastly, I would like to thank Idar for the love and support during all hard-working days.

Trondheim, June 2020

Anna Bellika Kjæmpenes

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Chapter 1

Introduction

In this chapter the motivation, background and goals for the master thesis is introduced. Research questions and objectives are stated, and an outline of the rest of the thesis is presented in the end.

1.1 Background and Motivation

Today, map animations are widely used to present spatial temporal data. The very first map animations were drawn by hand and each map frame recorded step by step. A lot has changed since then. Especially the rise of the world wide web gave unlimited possibilities for creating and sharing map animations with users. It is no longer the technology that set the limit for the amount of information presented in map animations, but the cognitive capacity of the human brain. Map animations are especially difficult to design given the fact that the data is presented over time, and the users must memorize what happened previously to understand the context. A poorly designed map animation with too much information presented will cause cognitive overload, and the learning effect will disappear. Therefore, it is important to have in mind how the cognitive process work, and which principles to follow to limit the cognitive load.

A discussed solution for enhancing the effectiveness of map animations, and lowering the cognitive load, is adding sound variables to make the animations multimodal. It is known that visual sensing is the most prominent form of sensing, but humans use several sensing channels when processing information. One of the pioneers discussing the use of sound in geographic visualization is Krygier (1994), which defined a set of abstract sound variables that can be used as a complement to visual and dynamic variables. Since then many researchers have suggested the use of sound to enhance the effectiveness of map animations (Midtbø, 2001; Cybulski, 2016; Harrower, 2007, e.g), but very few have studied the effect. Adding an additional sensing channel will, if executed well, add another layer of information and increase the capacity of the working memory. Hearing is an undervalued form of sensing which humans rely on in their daily life. As an example, visually impaired individuals function well without or with weakened visual sensing. They rely on other sensing channels, and especially hearing is important for them to orient themselves.

The most recent study on the use of sound in map animations was conducted by Hall et al. (2015). As stimuli for the experiment they used a map animation that utilized sound in several ways: introduction of new point types, to encode thematic information about the events and as a temporal legend. There were no statistically proven effect of sound in map animations, neither positive or negative. When suggesting for further work they enlightened the importance of limiting the functionality of the sound. It was hard to tell which of the sound variables had the greatest impact on the results.

There is a clear gap in the research on the use of sound in map animations. Although theory and prominent researchers suggest that sound will have a positive effect on the user's capability of perceiving information presented in map animations, it is yet to be proven. Based on the suggestions for further work made by Hall et al. (2015) this study was focused on only one functionality of sound variables in map animations: sound as attention grabber for specific events. If it is possible to verify or discard the effect, this would have an impact on how map animations should be designed to maximize its potential.

1.2 Research Objectives

The goal of this thesis is to study the effect of sound, as attention grabber, in map animations and deciding whether sound can be used to enhance the effectiveness of map animations. Despite the focus on the use of sound in map animation, very few researchers have studied the effect. Many researchers have suggested that adding sound and making the animation multimodal will increase the capacity of the working memory and enable the users to process more information simultaneously. The experimental study in this thesis is an attempt to fill a void in the research on the effectiveness of map animation. If the experiment is a success it will be possible to verify or discard the effect of sound as attention grabber pared with a visual variable. Before starting the experiment the hypothesis is that the users that is shown an animation with sound will perform better than the users that is shown an animation without sound, especially on questions regarding the visual variable associated with the sound variable. To measure the success of the experiment two research questions need to be answered:

1. How does sound variables, applied as attention grabbers, affect the effectiveness of map animations?
2. How does sound affect the performance, in terms of correct answers, of the participants? Is the group that is shown a map animation with sound better equipped to answer questions regarding the animation?

The target group of this experiment is all potential map readers that may be presented a map animation at some time. If it is in a work related situation or that the users see an animated map in the media is irrelevant. Therefore, it is desirable to have a spread in age, gender, work situation and level of experience in geographic science.

1.3 Research Methods

A literature study was conducted in order to get an overview of previous conducted work and theory connected to the research objectives. Next, a map animation was created as stimuli in the experimental study. Sound was applied as an attention grabber pared with a visual variable. To gather data for the experimental study a web-experiment was created and sent out to the participants. Lastly, the results of the experiment were examined and statistically analyzed. The results and findings were discussed and compared with results from previous research.

1.4 Outline

The rest of this master thesis is structured into four chapters: Theory and Related Work, Experimental Study, Results, and Discussion & Conclusion. Theory and related work present theory and previous work conducted on the use of sound in map animation. It also enlightens theory and other aspects needed for the experimental study. The chapter Experimental Study describes how the experimental study was designed and conducted. That includes description of the process of creating the map animation used for stimuli and designing the web-experiment. The following chapter is Results, which present the results of the experimental study. In Discussion & Conclusion, the results are discussed and compared with previous related work, ending with a conclusion whether the research was a success. In the end suggestions for further work is given.

Chapter 2

Theory and Related Work

In this chapter theoretical background and related work is presented. The theoretical background is needed to explain and discuss methods and concepts used in the thesis, and includes theory related to map animation, cognitive load theory, sonification and designing experimental studies. Related work will include work in the field of map animation, and especially the use of sound in map animations. This chapter will be the basis for the design of the experimental study and discussion presented in the following chapters.

2.1 Animated Maps

Map animations have been used to present geographic information for decades. In the early days animations were drawn by hand and a camera was used to record each map frame one at the time(Ma, 2010). We have come a long way since then, and the advance in technology have given cartographers endless opportunities for creating and sharing map animations directly to the users. In its simplest form a map animation is a series of static thematic maps. They are especially suited for spatial temporal data because time can be presented using time itself. What differentiate map animations from static maps are dynamic variables. The most used classification of visual variables in cartography was developed by Bertin (1967). He presented seven variables that can be used to encode geographic data in static maps: location, size, texture, shape, value, orientation and color. In addition to these visual variables a set of dynamic variables is needed to present dynamic data. First, DiBiase et al. (1992) presented the dynamic variables duration, rate of change and succession. Some years later MacEachren (1995) added frequency, distinguished display rate and synchronizations to the dynamic variables.

When designing map animations several aspects are important to have in mind. Harrower (2003) present tips for overcoming challenges with design of map animations. Based on Morrison (2000) identification of challenges of learning from and watching animations, Harrower (2003) present solutions for dealing with disappearance, attention, complexity and confidence. Because map animations changes frame by frame, users can experience disappearance just by blinking. To prevent this Harrower (2003) suggest letting the user see the animation several times (loop), adjust the frame rate or speed of the animation and including decay for visual variables. Deciding where to focus your attention when looking at a map animation can be a challenging task for a map reader. Suggestions for attaching users' attentions are to apply voice-overs or sound prompts, and use dynamic map symbols for critical moments. He states that it is important not to overdo the attention grabbers because it can be annoying and confusing for the user. Today, technology allows for creating complex map animations, and there are few limits for the amount of information you can visualize in a short period of time. If an animation is too complex the map readers will struggle to understand and perceive what is presented, it can cause split attention or change blindness. Harrower (2003) state the importance of data filtering, data smoothing and aggregation to restrain the complexity. Generalization and presentation of the most important aspects of the data is recommended. Morrison (2000) found evidence of a lack of confidence for knowledge acquired from animations compared to static graphic. To boost the map readers confidence Harrower (2003) suggest pre-training with an introduction section describing the animation. The suggestion of pre-training to enhance the cognitive perception is supported by Mayer et al. (2002) findings in their study on multimedia learning. The effectiveness of map animations is often discussed in literature. Limitations of map animations is not set by the technology, but humans' ability to perceive information. Therefore, to get a better understanding of the limitations of map animations it is needed to look at cognitive theories in connection to the field of geographic visualization.

2.2 Cognitive Load Theory

As suggested by Harrower (2007) cartographers are very good at studying the relative effectiveness of map design, but often fail to explain the result further than describing *what* worked best. To get a better understanding of *why* it worked best knowledge about human cognitive perception is required. The issue does not lay with the registration of changes, but rather the ability to perceive and memorizing the specifics of the change. Cognitive load theory(CLT) can be helpful for describing why this happens. John Sweller first developed CLT in the 1980's, and the fundamental aspect of CLT is that the cognitive overload can be reduced by paying attention to the role and limitation of the working memory. CLT describes structures of learning and information processing which includes, among others, the working memory and long-term memory of the human brain. Sweller et al. (1998) defines the working memory as consciousness and actively processing of information in the sense of comparing, organizing, or working on the information in some manner. When required to process information humans can probably hold up too seven items in their working memory, which limits the amount of information humans can process at the same time. Long-term memory is defined as the permanent storage of knowledge, and humans are not directly conscious about it. However, it is possible to bring large amounts of information from the long-term memory to the working memory when dealing with previously learned information(Harrower, 2007).

The working memory can be affected by the way material is presented, the activity given or by the intrinsic nature of the material (Sweller et al., 1998). There are several types of cognitive overload that can be connected to map reading tasks: intrinsic cognitive load, extraneous cognitive load and germane cognitive load(Harrower, 2007). Intrinsic cognitive load is dependent on the ability to isolate elements, meaning the higher complexity of the task the higher intrinsic cognitive load (Sweller et al., 1998). Extraneous cognitive load relates to the design of the material, and the cognitive load can be raised by poorly design or distraction by other elements. Lastly, germane cognitive load reflects effort of the user's engagement with the material. The user's attention must be drawn to processes which are relevant for learning, if not the cognitive capacity will be used unnecessary. Cartographers have explored different ways to deal with cognitive overload, usually either by increasing the amount of user control of the animation, or imposing more structure in animations in terms of segmentation of screens(Harrower, 2007).

Cognitive load in mulitmedia learning have been studied by numerous researchers(Mayer, 2002; Sweller et al., 1998, eg.). Mayer and Moreno (2003) emphasize three assumptions about how the brain work when processing multimedia: dual-channel, limited capacity and active processing. Information from verbal and visual material are processed separately via different channels. This indicate that it can be possible to lower the cognitive load by adding another sensing channel, making it multimodal. The processing capacity in the two channels are however limited, and it is important to not exceed these limits. In order to acquire meaningful learning, active processing in both the verbal and visual channels is needed. Figure 2.1 shows a visualization of how a multimedia learning process work. It describes how the working memory incorporate prior knowledge from the long-term memory in addition to processing and organizing the sensory impressions form both eyes and ears. Incorporation of prior knowledge from long-term memory emphasize that prerequisite knowledge about the theme or the medium presented have an impact on how much information a human can perceive. This indicates that people who are used to working with map animations or maps may have an advantage given their prior knowledge and skills. Studies on multimedia learning lead to Mayer's Modality principle which states:

> "Students learn better from animation and narration than from animation and on-screen text; that is, students learn better when words in a multimedia message are presented as spoken rather than printed text." —(Mayer and Mayer, 2001, p.134)

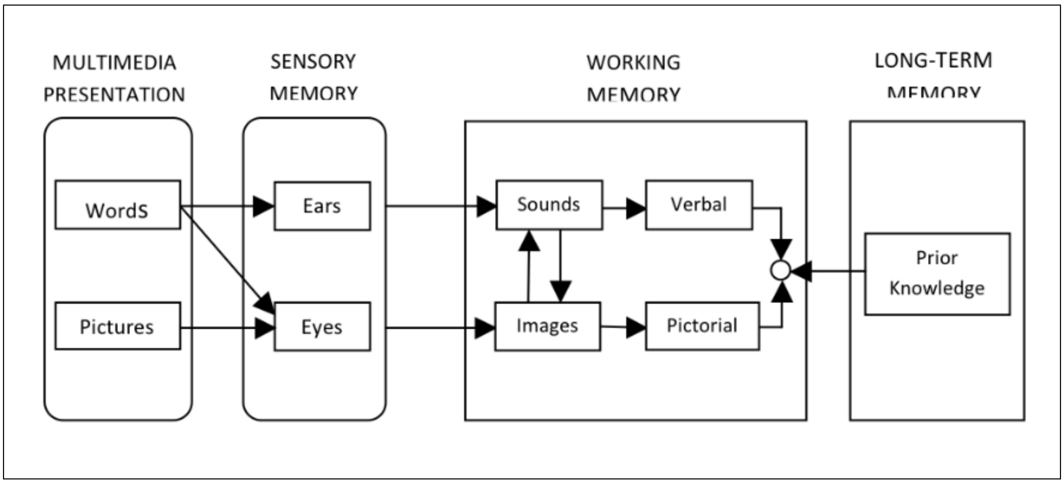


Figure 2.1: *Model of cognitive theory of multimedia learning (Mayer and Moreno, 2003, p.44)*

From this principle Mayer and Mayer (2001) presents three arguments for the use of sound in animations. First, adding sound will allow for accessing dual-channel capabilities of humans. Second, it will reduce the workload of the visual channel, offloading work to the hearing channel. Third, active processing is stimulated by forcing the learners to make connections between the information processed in the two channels. Multimodal presentations do not reduce the cognitive load, but they increase the working memory capacity(Harrower, 2007). Most studies on multimedia learning is conducted on students in classrooms, and not map readers, but the findings can be used to explain why the use of sound might help creating more effective map animations with some caution.

2.3 Sonification

Hearing is an undervalued type of sensing, humans depend on sound in their daily life. The first thing you sense in the morning is the alarm clock ringing, and when someone wants to get a hold on you the ringing tone on your phone will alert you. In traffic many accidents have been avoided because of the alerting effect of the car horn. Visually impaired rely on hearing to locate where they are, it amazing how well they function without the visual sense. Using sound to encode data have been discussed in literature for decades and is called sonification(Dubus and Bresin, 2013). Sonification can be defined as:

> "Sonification is defined as the use of nonspeech audio to convey information. More specifically, sonification is the transformation of data relations into perceived relations in an acoustic signal for the purpose of facilitating communication or interpretation." —(Kramer et al., 1999, p.3)

There are several sonification techniques. Dubus and Bresin (2013) present five of the most used techniques: audifiaction, auditory icons, earcons, parameter mapping sonification and model-based sonification. Audification is direct encoding of data streams as sound waves and does not require much processing to become audible. Auditory icons and earcons are similar, both are based on associating sound to distinct events. The difference is that auditory icons are based on natural sounds which directly can be associated to the event, while earcons are created by synthetic sounds and the association need to be learned. Parameter mapping sonification is the most used technique, and works in the way that a set of mappings between data dimensions and auditory dimensions is designed. It is simple to design and very effective because it has the potential to present information in a continuous way. Model based sonification is based on human's ability to associate sounds to its source, just like humans can differentiate between sound from different instruments. It is designed by defining a dynamic model which represent a system that can change over time.

In the field of geovisualization the use of sound to present data is often discussed. Krygier (1994) is one of the most prominent researchers in the field, and his proposal for abstract sound variables for use in geovisualization is often referred to. In Figure 2.2 Krygier (1994) presents a collection of abstract sound variables that can be used to present data as a complement to Bertin's visual variables.

The collection of sound variables is not a complete description of all sound variables that can

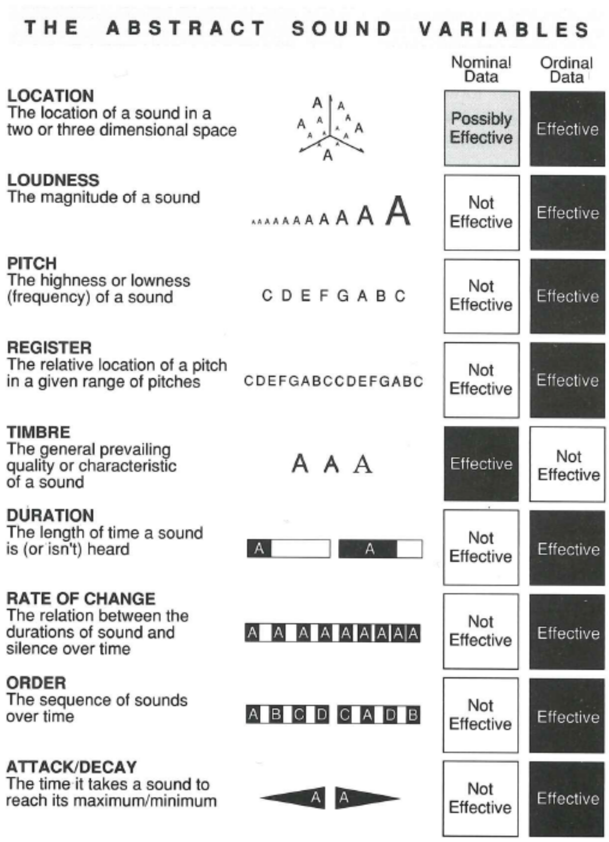


Figure 2.2: *The abstract sound variables presented by (Krygier, 1994, p.153)*

be used to represent data, but the ones that Krygier (1994) found most valuable in terms of presenting geographic information. Some details are required to fully understand the sound variables. These details are presented in the list below which is adopted from Krygier (1994).

- **Location:** this sound variable can map left/right, up/down and forward/backwards in a three-dimensional sound space. It can be used to direct the user's attention to a specific area in the map, and to present both nominal and ordinal data. As an example, it would be possible to use location to direct the user's attention to a specific area on a map. Stereo sound display is required in order to use location.

- **Loudness:** this variable is best suited for ordinal data because of its ordinal nature from quiet to loud volume. The loudness of a sound is measured using decibel. It can be used to represent ordinal data in the way where quiet sound represents a steady-state and change is represented by variation of the loudness. Loudness is also suited for implying direction and can be varied over time. When using loudness it is useful to think about the effect of turning of a constant sound like the sound of a vacuum cleaner or a kitchen fan.

- **Pitch:** the highness or lowness of a sound in terms of frequency. In addition to represent ordinal data, pitch can also imply location in a map. As an example, increasing pitch can represent upward movement. Human can distinguish 48-60 pitches which imply that pitch can be used to represent more than a single variable.

- **Register:** the location of a pitch is a set of pitches in a range of available pitches. It is a generalization of pitches, and are often divided into low, medium and high register.
- **Timbre:** describe the character of the sound and because of this the sound variable is well suited for nominal data. Think about how you can differentiate instruments by hearing the sound they make. The attention is drawn to the nature of the sound.
- **Duration:** the length the sound is heard or not heard. Duration is naturally ordinal.
- **Rate of change:** the relationship between the duration of sound and silence over time. The variable can represent consistent or inconsistent change of the data presented.
- **Order:** a natural order of sound variables can, for example, be from low to high. The order of the sound makes it possible to detect patterns or trends in the dataset. Order can also be used to present data that are out of chronological order or anomalies.
- **Attack/decay:** the time it takes for a sound to reach its maximum or minimum of a specific level of loudness. It can be used to present the spread of data.

All variables except timbre are well suited for ordinal data. For nominal data timbre and possible location are the best suited variables. Some of the variables, duration, rate of change and attack/decay, requires temporal data to be used. Dubus and Bresin (2013) have conducted a systematic review on sonification of physical quantities and conclude that the far most used sound variable is pitch. The second most used mapping is natural perception associations, meaning sound that can be related to natural events. As an example, sound associated with water can be applied when visualizing rainfall or a voice-over can be used to narrate a visualization.

There are several examples of the use of sound in geographic visualization. Vocal narration is an important application of sound to enhance geographic visualization, and is often used to provide an explanation about map animations(Krygier, 1994). Earcons and auditory icons are also possible to apply to enhance the attraction of important distinct events. In these cases, the sound variables are used as attention grabbers in combination with visual variables. Maps made for visually impaired often apply sound to present information, some of which only use sound to present geographic data. Heuten et al. (2007) conducted a study on interactive exploration of city maps created for visually impaired. They utilized the abstract sound variable location in addition to auditory icons to create a sound map. The goal was to create a tool which allowed for visually impaired to create a mental map of the city. Another example of an application which applies sound is Brauen and Taylor (2008) prototype of an audio-visual interface for an examination of Canada's trade with other world regions. Krygier (1994) discusses two map animations which applies sound to add additional information: a map animation of the diffusion of AIDS over time and space, and an animation of presidential election landslides. The AIDS animation utilizes loudness to represent the total number of cases an increase in loudness equals more cases. In addition, pitch was used to present the percentage increase of cases each year, which allows for finding anomalies in the dataset. The second animation, about presidential election landslides, use pitch to replace the temporal legend, where increasing pitch equals increasing years.

2.4 Sound and Map Animations

The use of sound variables in map animations have been discussed by several authors, many of which sees sound as a good way to present data in addition to visual variables(Midtbø, 2001; Cybulski, 2016; Harrower, 2007; Krygier, 1994, e.g). Midtbø (2001) present several suggestions for how sound can be used as a temporal legend in map animations. The abstract sound variables location, loudness, pitch, rate of change and duration could all be used to present time variations. Location can be used both to present time-cycles, using surround 4-channel sound, and time from one point to another. Loudness can represent time by changing the intensity of the sound when a specific event occurs. An audio temporal legend could reduce the chances for split attention, because both the eyes and ears are engaged at the same time(Harrower, 2007). Results from a study on animated maps online, conducted by Cybulski (2016), show that 38 percent of map animations on the internet applied sound in some way, usually instead of a temporal legend. However, there are few experimental studies on the use of sound in map animation mentioned in literature.

The most recent study on audio-enhanced map animation was conducted by Hall et al. (2015). They explored the possibility of sound being used to enhance the effectiveness of an animated map. The stimuli for the experimental study was an artwork called ”1945-1998”[1], which was a presentation of location and time for all known nuclear detonation in the timespan. This animation utilized sound in several ways; an audio-temporal legend for months and years, every detonation were represented with a beep, and the pitch of the beep was specific for each country. The test was conducted as a web-experiment, where the test persons were divided into two groups: with sound and without sound. Four different parts of the artwork were presented in the test with six complementary yes/no/cannot tell questions. The results of the study were inconclusive, no significant difference was found between the two groups. However, some interesting trends were found. It turns out that the added sound had a more positive impact on the spatial task when there were few events. For the temporal task, the added sound had a positive influence when there were many events. It was pointed out that the design of the study might be the reason why the results were inconclusive. They also state the importance of thinking about sonification in a different way than the visual variables. The visual elements of

[1] https://www.youtube.com/watch?v=cjAqR1zICA0

a map animation require attention piece for piece, while you can constantly hear sound without giving it very much attention. For further research they recommend applying one sound variable at a time. Then it will be possible to identify and isolate the cause that affects the user's ability to perceive information. One of the functionalities they recommend to explore further is sound as attention grabber, and especially if attention grabbers can be used to minimize change blindness.

2.5 Web-experiment

Planning an experimental study is difficult, and it is helpful to follow some guidelines. Kitchin and Tate (2013) present seven stages of statistical investigation. First you need to understand the problem, and state what you are trying to achieve. Second, collect the data. Third, verify the quality of your dataset and pre-process the data for statistical analysis. Fourth, describe your data and do an initial examination. Fifth, after the initial examination and pre- processing of the data it is time for statistical analysis. Select an appropriate method, which fit the results and provide the information needed to answer you research questions. Sixth, compare your results with previous research in the field of study. Lastly, interpret and present the results from the experimental study.

The choice between unsupervised web-experiment and supervised laboratory test need to be considered carefully. It has consequences in terms of data quality and the burden on researchers and test participants(Clifford and Jerit, 2014). There are many advantages to web-experiments. First of all, it is easy to distribute and possible to reach a broad audience without raising the costs of the experiment(Clifford and Jerit, 2014; Reips, 2002; Couper, 2000). web-experiments also offer ease of access, the experiment is brought to the users and there is no need to show up physically(Reips, 2002). This leads to the advantage that web-experiments take less time to finish than supervised tests. There are however some drawbacks with web-experiments. The researchers have little experimental control, which can lead to uncertainty in the results. There is no interaction with the users, and to gain an insight into their thinking and perception of the test is difficult. In addition, there is no control over the test environment. Each participant will be in different physical environments, and it has to be expected that the results can be influenced by the participants distractions(Midtbø and Nordvik, 2007; Clifford and Jerit, 2014; Kettunen and Oksanen, 2018). In contradiction, this can also be an advantage. The participants will take the experiment in a natural environment, which will be similar to the environment the stimuli could be presented. Another drawback is the difference in devices and browsers used to take the experiment(Midtbø and Nordvik, 2007; Reips, 2002). It is important to make sure that the web-experiment works the same for all possible types of devices and browsers.

Researchers have conducted studies on the differences between web-experiments and supervised tests. Results presented by Clifford and Jerit (2014) state that web-experiments is a good alternative to supervised tests. The most significant issues were distractions for the participants that took the web-experiment, but the distractions did not cause big difference in performance. A study conducted by Kettunen and Oksanen (2018) on the effect of unsupervised participation, in a usability study about map animation, confirms the findings of Clifford and Jerit (2014). Their results suggest that web-experiments is an appropriate alternative for research in geo-visualization.

2.6 Summary

Theory and related work presented in this chapter form the theoretical framework for the rest of this thesis. When creating a map animation it is important to have in mind the limitations and the suggestions for dealing with these limitations. Cognitive load theories can be used as a helpful tool for explaining why specific results occur, rather than just stating what happened. The functionality of the human perception is important to have in mind when attempting to design more effective map animations. Theory and prominent researchers suggests that making an animation mulitmodal will increase the working memory capacity by dividing the workload into separate sensing channels. There are several sonification techniques and sound variables that can be utilized for creating effective map animations, but the choice of method and sound variable need be considered carefully. The focus in this research is based on previous research on the use of sound in map animations, and especially the recommendations for further work stated by Hall et al. (2015) has been an important starting point. The importance of isolation of only one functionality of sound variables lead to the focus on sound as attention grabber in this research. An experimental study was designed and conducted based on the theory presented. Deciding which method used to collect data was based on the findings on several studies comparing web-experiments and supervised tests. It is important to have in mind that the lack of experiment control and different test environments may be a disadvantage for web-experiments, but the results of the studies show that this had little impact on the results. All decisions and the discussion presented in the following parts of this thesis is based on the theory presented in this chapter.

Chapter 3

Experimental Study

This chapter describes the experimental study conducted to explore the effect of sound in map animations. First, the creation of the map animation, used as stimuli in the experiment, is described. Followed by a presentation of the design of the web-experiment and a description of the test procedure. In the end the participants are presented.

3.1 Map Animation

Stimuli for the experimental study was an animated map of significant earthquakes worldwide. Earthquakes are distinct events with specific positions that occur regularly over time. Therefore, this topic is well suited for a map animation. Because the goal of the study was to test the participants ability to comprehend what is presented in the animated map, and not their knowledge about the topic, it was necessary to find a topic that very few are experts in, but most have some prerequisite knowledge off. Originally the plan was to create a map animation of the spread of the corona virus worldwide. This plan was rejected given the circumstances at the time the thesis was written. The corona virus situation quickly escalated, and most people would have too much prerequisite knowledge about the topic. Also, the participants would probably have seen similar animations in the media, which would give them an advantage when answering questions in this study. The experiment was not designed to test the participants prerequisite knowledge or skills, the goal was to test their ability to analyse and process the information presented in an animated map.

3.1.1 Dataset

The dataset used to create the animation origins from NCEI/WDS Global Significant Earthquake Database (National Geophysical Data Center and World Data Service , 2020). This is an open database created by National Geophysical Data Center(NGDC) and World Data Service(WDC), and is hosted by NOOA's National Center for Environmental Information (NCEI). NCEI is the United States leading authority for environmental data. The Global Significant Earthquake Database contains over 5,700 earthquakes from 2150 BC to the present. An earthquake is defined as a significant earthquake, by the NCEI, if it caused deaths, caused damage (over approximately $1 million), generated a tsunami or is measured to have a magnitude of 7,5 or more. Only earthquakes in the period from 2000 to 2020, and with a damage degree of 3 or 4 were included in the dataset used for the animation. Earthquakes that cause severe damages are categorized as damage degree 3 and earthquakes that cause catastrophic damages are categorized as 4. Figure 3.1 shows the distribution of all 245 significant earthquakes in the dataset used in the map animation. Attributes for the earthquakes include the date of occurrence, location, measured parameters, and damage effects. Figure 3.2 shows an example of the information provided for one specific earthquake in the dataset.

Figure 3.1: *Distribution of the 245 significant earthquakes in the dataset.*

Significant Earthquake

Date						*Earthquake Location*			*Earthquake Parameters*							
									Focal Depth	Magnitude						MMI Int
Year	Mo	Dy	Hr	Mn	Sec	Name	Latitude	Longitude		Mw	Ms	Mb	Ml	Mfa	Unk	
2000	1	11	23	43	56.4	CHINA: LIAONING PROVINCE	40.498	122.994	10	5.1	4.7	4.9				

Earthquake Effects												*Total Effects (Earthquake and Tsunami, Volcano, etc.)*											
Deaths		Missing		Injuries		Damage		Houses Destroyed		Houses Damaged		Deaths		Missing		Injuries		Damage		Houses Destroyed		Houses Damaged	
Num	De	Num	De	Num	De	$Mill	De	Num	De	Num	De	Num	De	Num	De	Num	De	$Mill	De	Num	De	Num	De
				30	1		3	3600	4	8800	4					30	1		3	3600	4	8800	4

Figure 3.2: *Data entries for one specific earthquake in the Significant Earthquake dataset. The attributes include date, location, parameters and damage effects (National Geophysical Data Center and World Data Service , 2020).*

3.1.2 Apparatus

The animated map was created using Carto, which is a location intelligence platform that can be used for analyzing and visualizing geographic data[1]. Carto is a service as a software and requires a license for unlocking all functionality. The license used for this thesis was provided via the GitHub Student Developer Pack[2], which is free for all students. Many different tools were discussed, and the most important requirements were functionalities for animating geographic data and adding sound variables. Unfortunately, it was not easy to find a tool that had such a combination of animating maps and adding sound variables. Not un-expected given the lack

[1]https://carto.com/
[2]https://education.github.com/pack

of studies on map animation that applies sound variables. Conventional animation tools, like Adobe Animate, have the functionality for adding sound variables, but presenting geographic data is quite complicated. Geographic information systems(GIS), like QuantumGIS and ArcGIS, have the functionality for animating maps, but not adding sound variables as attention grabbers. Carto did not fulfill the sound requirement but was chosen despite of this. The functionality of preparing and editing the dataset using Python and many different design options for animations weighed up for that. Sound variables were added manually to a video recording of the animation using Adobe Premiere Pro[3].

3.1.3 Creating the Map Animation

Preparing and editing the dataset was done using the Python data analysis library Pandas. The dataset was downloaded as a tab-delimited CSV file and read into a Pandas DataFrame. To be able to create the animation, point geometry and datetime columns were created and added to the dataframe. Animation of the significant earthquake dataset was done using Carto Python API and Carto Builder. The Carto builder allowed for interactively designing the map via a user interface but had some limitation. As an example, it was not possible to edit the duration the dots on the map was shown via the user interface. These limitations were avoided using the JavaScript editing functionality, which provided more functionality and options.

The map animation was designed based on the goal of the thesis. It was important to have in mind that the animation would work as a stimulus in an experimental study, to test the effect of sound as attention grabber in map animations. Figure 3.3 is a still picture of the animation, and show all visual elements. The most important aspect of the animation is the background map, which does not change during the animation. It was important to find a map with clear borders and display of country names. In addition, the background map needed to contrast with other visual variables to highlight their appearance in the animation. A black background map with white borders and names was chosen based on the requirements. The type of map visualization used in the animation was a dot map, where each dot represents a distinct earthquake event at a given time. The dots appear in order of date of occurrence and disappears after around two seconds. All earthquakes were categorized as either an earthquake that caused sever damages (3) or catastrophic damages (4). The earthquakes was presented in the map using two colour variables, yellow and red, for the dots. When an earthquake appears as a yellow dot it indicates that the earthquake caused severe damages, and a red dot indicates catastrophic damage. The colours were chosen because red and yellow often are associated with danger, and the two colours are easily separated visually. A legend was added to the top left corner in order to present the encoding of the two colors. For the user to be able to follow the timespan a temporal legend was placed in the bottom. This timeline spans over the period presented in the animation,

[3] https://www.adobe.com/no/products/premiere.html

and each column represents the number of earthquakes for each month.

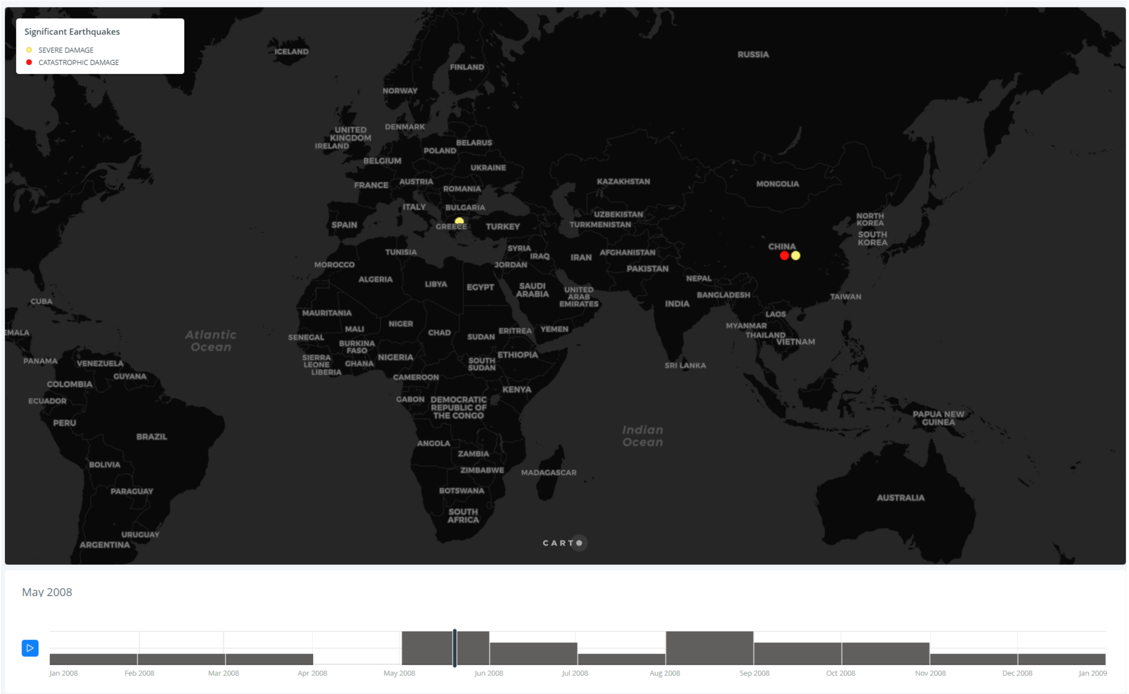


Figure 3.3: *Still image of the map animation of significant earthquakes worldwide.*

Adding the sound variable was challenging given that the functionality of adding sound to map animations was not yet available in Carto. A solution for this problem was to manually add sound to a video of the animation using Adobe Premier Pro. The choice of sound variable needed to be considered carefully. First, the sound variable should work as an attention grabber for specific events. Second, it should be an abstract sound variable with no association to the topic. This because it is hard to find a universal sound that all people associate with earthquakes. Association to sound can differ from person to person, and cultural affiliation can be a reason for this. Based on the two requirements a short tone-beep sound was chosen. The sound can best be described as a short beep sound with a change in pitch, and suits perfect as an attention grabber. The sound was used to highlight the appearance of red earthquakes (catastrophic damages) in the animation. A few moments before a red dot appears the sound starts playing to grab the user's attention. It is a very short sound and does not last the whole time a red earthquake is displayed. Regarding the abstract sound variables presented in Chapter 2, the sound variable used in this experiment is a combination of several. First, it can be described as an earcon. It is a fully synthetic sound connected to a distinct event and the user has to learn the association. Second, it utilizes the rate of change in the way of breaking the silence every time a red earthquake appears.

3.2 Web-experiment

It was decided to conduct a web-experiment to collect data for the experimental study on the effect of sound, as an attention grabber, in map animations. As presented in Chapter 2 there are advantages and disadvantages of web-based testing compared to supervised testing. Web-experiments are effective in terms of recruiting participants to a large extent and availability. It allows participants to conduct the test wherever and whenever suits them best. Besides, web-experiments are less time-consuming than supervised laboratory tests. The test environment will be more realistic, and the participants will be in a real-world scenario similar to a situation where they would be presented a map animation. One disadvantage of web-based testing is that it is not possible to supervise how the participants react to and comprehend the material in the test. There is less control over the test situation and you cannot use the think-aloud method to gain information about the participants reasoning. In retrospect, the decision to conduct a web-experiment was the best given the corona situation. Because of the requirement of social distancing, and the fact that the university was closed it would be challenging to execute a supervised test. A print of the web-experiment that was sent out to the participants can be found in Appendix A.

3.2.1 Test Design

The format of the web-experiment was one page at the time, excluding the possibility to go back to previous pages. This was important to prevent participants from looking at the questions before the animation. If they knew the questions beforehand it would be easy to look for the answers, and it would not facilitate analytic reasoning. In total the web-experiment consisted of 33 questions and ten pages. with an expected length of 7 minutes. The experiment was divided into five parts: Introduction, Part 1, Part 2, Feedback and Information about the participant. First, the participants were given an introduction to the web-experiment and the animation used as stimuli, followed by an introduction test. The introduction test was given to help the participants get to know the animation, the sound variable and the layout of the experiment. Results from this part were not included in the experiment this part was just meant for training. An introduction test was necessary for excluding any misunderstandings and to raise the participants level of confidence for the rest of the test.

The main part of the experimental study was Part 1 and Part 2. Both Part 1 and 2 had the same set up. First, a map animation was presented on a separate page. The participants were instructed to see the video of the animation once without pausing before pressing next. Following, questions about the animation they just saw were asked. The difference between Part 1 and Part 2 depends on which group the participants were placed in. Group A saw the animation in Part 1 with sound and the animation in Part 2 without sound, and the opposite for group B. All questions were the

Table 3.1: *Overview of all animations used in the web-experiment.*

Part of the survey	Year	Number of earthquakes	Duration	YouTube-link
Training test	2006	Total: 6 Red: 2 Yellow: 4	9 seconds	https://youtu.be/Kyl642LBEA8
Part 1	2008	Total: 16 Red: 3 Yellow:13	20 seconds	https://youtu.be/YtmdLVmDtuw
Part 2	2018	Total: 10 Red: 5 Yellow: 5	25 seconds	https://youtu.be/A6QyUUdLkJY

same for the two groups. Feedback and information about the participant were placed at the end of the web-experiment. These types of questions are often seen as boring, and if placed in the beginning there is a risk the participants will lose interest and drop out. Of course, the feedback section needed to be placed after the main experiment to allow the participants to give feedback on the web-experiment.

The animations in the three parts of the web-experiment (Introduction, Part 1 and Part 2) were not presenting the same data. Three sections of the map animation of significant earthquakes 2000-2020 were chosen. Each section represented the occurrence of earthquakes in a specific year, with different duration and different distribution of red and yellow earthquakes. Several parts of the animations were considered as stimuli. The initial plan was to split the animation for the whole period (2000-2020) into three parts. This would have resulted in three very long animations with way too much information to process in a short period; the cognitive load would be too high. It became clear that the issues were duration, speed, and distribution of red and yellow earthquakes. Too long duration would result in participants struggling with memorizing the information presented and a risk for them to lose their interest in the experiment. If the animations were too fast the participants would have troubles noticing all earthquakes presented and split attention and change blindness would occur. Duration and speed of the animation is a whole other study area and was not tested in this experiment, but applied with caution. The distribution of red and yellow earthquakes varies in the stimuli for the experimental study. The animation in Part 1 has an overweight of yellow earthquakes, while Part 2 has a 50/50 distribution. It would therefore be possible to see if the distribution of earthquakes had any effect on the results. The animations were included in the web-experiment by uploading videos of the animations to YouTube and embed them into a text question. An overview of all the animations used as stimuli can be found in Table 3.1, including the distribution of red and yellow earthquakes, duration and links to the YouTube videos. For Part 1 and 2 the animations were uploaded both with and without sound.

When designing a web-experiment, it is important to formulate precise and clear instructions and questions. There should be no room for misinterpretation of the instructions or questions. The questions were designed in a way that would reflect analytic reasoning, which is not an easy task. It would be difficult to analyze the results if the participants were to be asked to list everything they remembered from the animations. Some simplification of the questions was therefore needed, and a rigorous study design was chosen. The main part of the experiment, Part 1 and Part 2, only had closed-ended questions designed for quantitative analysis. Some questions in Feedback and Information about the user were designed for qualitative analysis and were open ended questions. The rest of the questions were needed to gain information about the participants and their thoughts about the use of sound in map animations.

For Part 1 and Part 2 the set up was the same. First, participants were asked to watch the video of the animation thoroughly one time, and focus on the number of earthquakes of the two categories and position of the earthquakes. Unfortunately, there is no control over how many times the participants saw the video or paused it. Therefore, this was a possible source of error because it is needed to trust that the participants follow the instructions correctly and does not get tempted to see the animation several times. Second, after watching the video they were asked 5 questions based on the animation. The questions were given after the animation, to encourage analytic reasoning. If the participants knew the questions beforehand it would be easy to look for the answers. A map corresponding to the background map in the animation was added before the questions to help the participants. The goal of the study was not to test the participants knowledge in geography, and the map would help them locate a specific country if they were unsure. The questions were designed to test the effect of sound, focused on the visual variables red and yellow and were closed-ended. The closed-ended questions had a set number of options and only one answer was allowed per question. Three of the questions were of the type one-row matrix questions with options 1 to 6. These questions focused on the number of earthquakes in the two categories. An example of these questions is: ”How many earthquakes of the category catastrophic damages(red) were presented?”. The two last questions were of the type multiple-choice questions, with options True, False or Cannot tell. These questions were allegations focused on the location of the earthquakes, and one was designed to test if the participants were able to separate what was presented in the animation and not. An example of these allegations is: ”There was 1 earthquake of the category severe damages(yellow) in Greece?”. Table 3.2 present all questions with alternatives and correct answers for the introduction test, Part 1 and Part 2.

Feedback and information about the participants included some questions for qualitative analysis. These questions were included to gain an insight into the participants thought about the use of sound in map animations and the design of the web-experiment. An overview of all questions in the last two parts of the web-experiment can be found in Table 3.3. The first question in the

Table 3.2: *Table of all questions in the Introduction test, Part 1 and Part 2, including answer alternatives and correct answers.*

Part of the survey	**Questions**	**Answer alternatives**	**Answers**
Training test	Q1: How many earthquakes of the category catastrophic damages(red) were presented?	One-row matrix: 1-6	2
	Q2: There was one earthquake of the category severe damages(yellow) in China	Multiple-choice: True/False/Cannot tell	True
Part 1	Q1: How many earthquakes of the category catastrophic damages(red) were presented?	One-row matrix: 1-6	3
	Q2: How many earthquakes of the category catastrophic damages(red) were there in China?	One-row matrix: 1-6	2
	Q3: How many earthquake of the category severe damages(yellow) were there in India?	One-row matrix: 1-6	1
	Q4: There was 1 earthquake of the category severe damages(yellow) in Greece	Multiple-choice: True/False/Cannot tell	True
	Q5: There was 1 earthquake of the category catastrophic damaged in Russia	Multiple-choice: True/False/Cannot tell	False
	Q6: Was there sound in the animation you just saw?	Multiple-choice: yes/no	Yes/no
Part 2	Q1: How many earthquakes of the category catastrophic damages(red) were presented?	One-row matrix: 1-6	5
	Q2: How many earthquakes of the category severe damages(yellow) were presented?	One-row matrix: 1-6	5
	Q3: How many earthquakes of the category catastrophic damages(red) were there in Italy?	One-row matrix: 1-6	1
	Q4: There was more than 1 earthquake of the category severe damages(yellow) in China	Multiple-choice: True/False/Cannot tell	True
	Q5: There was one earthquake of the category catastrophic damaged(red) in Papua New Guinea	Multiple-choice: True/False/Cannot tell	True

feedback section was ”On a scale from 1 to 10 (where 10 is very difficult) how difficult did you think the test was?“. In addition to the results of the experiment, this question could help determine whether the test was too difficult. The questions regarding technical issues and instructions were important to ensure the quality of the results. If technical issues occurred or the participants did not follow the given instructions it could have an impact on the results. These questions had a ”please specify” text box, so that the participants could explain the particular issues, which made it possible to remove answers from the specific participant if it was considered a significant error. The most important question for the qualitative analysis was ”What do you think about the use of sound in map animations?”. This would give an insight into what the participants felt about the sound in map animations. Five options were given, which reflected different aspects the participants might think about the use of sound in map animations. There is a chance that someone chose the option ”Sound helps emphasizing specific events”, because they thought it would be the correct answer given the focus of the study. Another alternative considered was an open-ended question regarding sound in map animations, but this was not used because of the difficulty of analysing these types of questions. Instead, a comment field was added to provide the opportunity for the participants to comment on all aspects of the web-experiment. This comment field was voluntary, and the participants was allowed to skip it if they did not have anything they wanted to say. In the end of the web-experiment a page containing questions about the participants was added. This information was needed to examine if the sample could represent the target group in terms of gender, age and work situation. It is necessary to be careful about these types of personal questions because of GDPR (General Data Protection Regulation) and the personal protection of the participants. A question about GIS (Geographic Information Systems) experience was added in the end to ensure that not only expert or inexperienced persons were included in the test group. The level of expertise in GIS can have an impact on how you analyze the map animation, and it was expected that the participants with the highest level of expertise would have a higher percentage of correct answers.

All the participants were randomly divided into two groups using A/B testing on the animation in Part 1. The first group saw the animation in Part 1 with sound and Part 2 without sound, and the opposite for the second group. They all answered the same questions. It was discussed to partition the participants into one group with sound and another without, but this would provide less data than the method chosen. Unfortunately, there was an issue with the A/B testing. The plan was to use A/B testing for the animation in Part 2 as well, but the groups were not divided in the same order. The participants would have been divided into four groups instead of two, which would lead to some groups were the participants saw both animations with sound or both without sound. To solve this issue a question was added to Part 1: ”Was there sound in the animation you just saw?”. Page skip logic was added based on the participants answers. If the answer was yes they were sent to the animation without sound in Part 2, and with sound if

Table 3.3: *Table of all questions in Feedback and Information about the participant, including answer alternatives.*

Part of the survey	**Question**	**Answer alternatives**
Feed-back	On a scale from 1 to 10 (where 10 is very difficult) how difficult did you think the test was?	Slider or input of integer: 1 - 10
	Did you have any technical issues?	Multiple-choice: Yes/no(please specify)
	Did you follow all given instructions?	Multiple-choice: Yes/no(please specify)
	What do you think about the use of sound in map animations?	Multiple-choice: Sound is distracting. Sound makes no difference. Sound helps emphasizing specific events. Sound takes away the focus on other elements. Sound is confusing.
	Do you have any comments regarding the survey?	Open text question
Information about the participant	Gender?	Multiple choice: Male/female/do not want to answer
	Age?	Multiple-choice age groups: Under 18/18-28/29-39/40-65/over 65
	Which of the following options suits you work situation?	Multiple-choice: Student Professional income-generating work Part-time employee Unemployed or jobseeker Retiree Military service Temporarily laid off Parental leave Disability pension Other
	What is your level of expertise in GIS(Geographical Information Systems)?	Multiple-choice: Expert/Good experience/ Some experience/ No experience

the answer was no. This means that you have to trust the participants to answer correctly, and there is a chance someone chooses the wrong answer. In theory, this would work fine, but there was a chance for someone to be confused by the animation in the introduction test, which was shown with sound for all participants. It is possible to check this in the results and remove the participants that failed, but you risk losing valuable data. Another measure added to avoid bias in the results is randomizing the order of the answer options for some of the question. People often tend to choose the first option they see fit even though there might be a better-suited option. All the questions, except the comment question, was sat to require an answer, meaning that is was not possible go to the next page without answering all required questions.

3.2.2 Apparatus

Because of the time frame of this master thesis it was not viable to implement a custom test-tool. It was argued that a custom test-tool would be the best solution because of the lack of customization for testing geographic applications in ordinary survey tools. However, there are many great web test-tools available. The most important requirement for the experiment tool was that the animation needed to be included in some way. Second, there needed to be functionality for randomly dividing the participants into two groups. The experiment-tool chosen for this study was SurveyMonkey[4], which provides a cloud-based software as a service for online surveys. It is free to use, but some functionality requires a license. The license used for this experimental study is called Advantage and is provided by the Department of Civil and Environmental Engineering at NTNU. There are several reasons why SurveyMonkey was chosen. First, it is user friendly, has many different design options and different types of questions. It is possible to create a professional web-experiment easily. Second, it has the functionality of adding video via YouTube, meaning it is possible to present the animation in the web-experiment. Third, it has the functionality of A/B testing, which means that you randomly can divide theparticipants into two or more groups. Besides, it is effortless to share the web-experiment with the test participants via a web-link. SurveyMonkey also allows for directly overview and analysis of the results, and you can download the results as a CSV, pdf file or a SPSS datatable for further statistical analysis.

3.2.3 Pilot Study

Designing the web-experiment was a long process. Before sending out the web-experiment on a big scale, a pilot study was conducted. A pilot study is helpful to exclude errors, refine the formulation of questions, test logic and remove misunderstandings. Feedback from the pilot study was valuable, and improvements based on this feedback could have improved the results

[4] https://www.surveymonkey.com/

of the experimental study. When working on the design of the web-experiment for an extended period it is hard to evaluate you own work. Evaluating the level of difficulty of the questions was very hard because the animations were too familiar. A pilot study provides the possibility to gain new insights on your work from outsiders that have not been a part of the design process.

Six persons in close relations to the author received the web-link and answered the questions in the web-experiment. It was essential to gather a group of persons with a spread in age and in level of expertise in IT and GIS. Each of the test participants were asked to use a specific device or web-browser, to ensure that the web-experiment worked on all types of devices and browsers. After completing the web-experiment the participants was interviewed and gave feedback on their perception of the web-experiment. Key takeaways from the interviews and results of the pilot study lead to several changes in the web-experiment design.

All the participants had comments about the speed of the animation compared to the number of earthquake events. They said it was too fast, had too long duration and that it was hard to notice all the earthquakes if several were presented at the same. As a result of these comments the speed and duration of the first draft of the animations were edited. Instead of splitting the original animation from 2000-2015 into three pieces, the animations presented one year at the time. This way it was possible to slow the animation down, limit the number of earthquakes, keeping the duration of the three animations short. Another comment was the formulation of the questions. Some of the test participants felt some of the one-row matrix questions were too vague. This was fixed by removing terms like around and circa. One participant noticed that there was a lack of specification on the scale in the question of difficulty. Therefore, a specification saying that 10 is very difficult was added to the question.

Some technical issues were discovered during the pilot study. Different types of devices were tested; windows laptop, mac, Android phone, iPhone and android tablet. Also, several browsers were tested; Safari, Chrome, Edge and Mozilla Firefox. Answering the web-experiment worked for all devices and browsers, but there was a problem with the size of the videos of the animations. It was very hard for the participants using a mobile phone or tablet to see what was going on in the animation; everything appeared very tiny. Based on this all participants in the experimental study were asked to conduct the test using a PC. There was another technical issue regarding playing the video of the animation. In the pilot study all participants were asked to see the animation twice. First, there was no possibility to check if they actually saw the animation twice. Second, when the video ends YouTube automatically show suggestions for other videos, which was very confusing for some of the participants. One participant commented that it was very difficult to find the replay button and experienced getting lost in the YouTube suggestions. It was decided to ask the participant only to see the animation once, to avoid such technical issues.

Despite the participants complaining about the speed of the animation and that the test was difficult, the overall performance on the pilot study was good. This might implicate that the participants are not used to deal with such types of test and lack confidence in their analytic skills. Instead of changing the question types, one of the animations was replaced with another. Both the animations in part 1 and part 2 had the same distribution of red and yellow earthquakes in the pilot study. One participant commented that there should be more red earthquakes with sound. Therefore, the replacement animation had a 50/50 distribution of red and yellow earthquakes. This opened for analyzing the difference of the number of earthquakes combined with sound. When analyzing the results another issue appeared. Initially the plan was to use the slider question type (like the question about the difficulty in the feedback section) for the three first questions regarding the animations. The slider question type is considered as an open-ended question, which does not work well in quantitative analysis. Therefore, the question type was switched to a one-row matrix question.

3.2.4 Participants

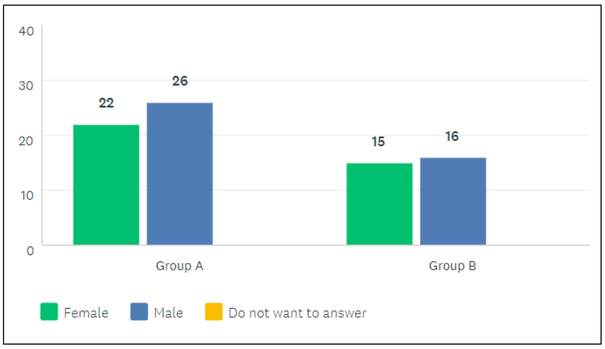
The web-experiment was distributed to several social groups via e-mail and messenger. All potential participants received a web-link of the web-experiment, which was written in Norwegian. They were all advised to take the web-experiment on a computer because of the small size of the video of the animation on other devices. Distribution of the web-experiment was divided into two steps. In the first step contacts of the author were contacted, and asked to take the experiment. In addition, some of the participants were asked to contact others that might be interested taking the web-experiment. A template e-mail was sent out to forward, and the goal was to create a snowball effect for recruiting more participants. People tend to be more trustworthy of people they know, and therefore getting others to forward the web-experiment would potentially lead to more participants. The distribution of the web-experiment was divided into two steps in order to fix eventual small errors after the first dispatch.

The first group that received the web-experiment was contacts of the author, mostly fellow students, friends, family and acquaintances. In total 49 participants answered, with an average time of 7 minutes and 56 seconds. The completion rate was 95% meaning very few persons dropped out. All partial responses were removed. Ten of the 49 participants was discarded because they failed to answer correctly regarding sound in the animation in Part 1. 8 saying they saw the animation with sound when shown an animation without, and 2 participant saying they did not see the animation with sound when shown an animation with sound. This question was connected to the skip logic and the participants needed to answer the question correctly. If not, they would see two animations with sound or two animations without sound. It was expected that some would fail on this question, but not such a high number. This was considered as a flaw in the web-experiment design. To reduce the problem in step 2 of the distribution, the question "Was there sound in the animation you just saw? was added after all animations in the experiment (Introduction test, Part 1 and Part2). This seemed to work to some extent, but several participants needed to be discarded in the second step as well.

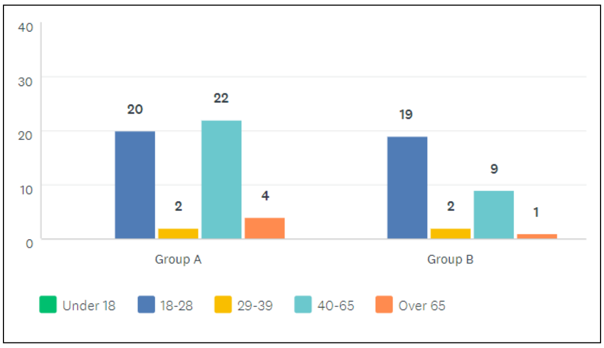
In the second step of the distribution the web-experiment was included in a newsletter to all members of GeoForum, including 1800 persons. Unfortunately the timing of the dispatch was not good, it was sent out just before a holiday, and the number of respondents was lower than desired. Therefore, an additional effort was made to recruit more participants in the last three days before closing the web-experiment. In total there were 48 respondents in the second group. The completion rate was 96% and the average time spent was 7 minutes and 7 seconds. All partial responses were removed. Also in this group some of the participants were removed based on the same issue as the first step. In total 7 of the 48 responses were removed. Three participants said they did not see an animation with sound when they should have seen one with sound, and 4 participants said yes when they should have seen an animation without sound. One additional participant was removed based on the question "Did you follow all given instructions?". The participant admitted seeing the first animation twice which may give an advantage for answering the rest of the questions.

To summarize, the total number of respondents was 79, after discarding the 18 respondents. Since 17 respondents needed to be removed because they failed on the question regarding sound in the animation, it is fair to conclude that the functionality for randomly dividing the participants into two groups did not work properly. It is very unfortunately discard answers from 17 participants, which could have contributed with valuable data for the experiment. The number of participants in the two groups was uneven with a 60/40 division, 48 participants in group A, which started with an animation with sound and 31 in group B which started with an animation without sound. Asking the participant if they followed all instruction given was designed to play on the participants conscience. Only one participant was excluded, but the fact that the question was answered honestly imply that most of the participant did follow the instructions. None of the other participants was defined as outliers in the statistical test, meaning none of the participants performed remarkably worse than others.

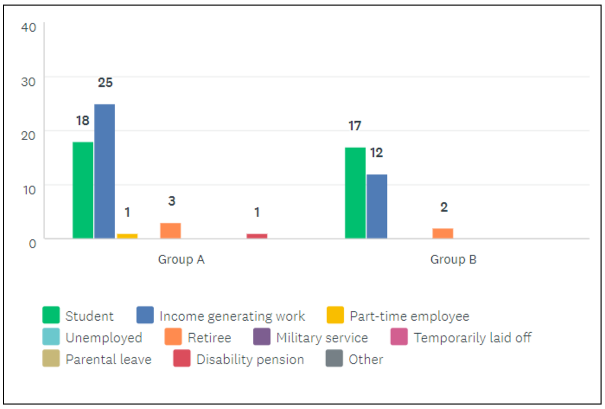
Data about gender, age, work status and GIS expertise of the participants were collected in the end of the experiment. A presentation of the data can be seen in Figure 3.4, where group A saw the animation with sound in Part 1 and without sound in Part 2, and the opposite for group B. As displayed in the figure there are more male respondents than female, with a difference of 4 in group A and 1 in group B. There are two age-groups that are dominant; 18-28 and 40-65. This clearly reflect the author's social network. Regarding work status, most of the participants are students or have income-generating work. The question regarding GIS-expertise was added to get insights into how familiar the participants were with working with geographical data. Based on the theory, people that have prerequisite knowledge and skills about maps may perform better



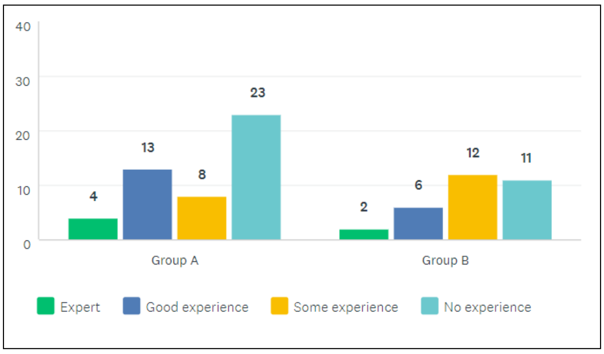
(a) Gender



(b) Age



(c) Work Status



(d) GIS expertise

Figure 3.4: *Data about the participants in the two groups A and B. Including gender(a), age(b), work status(c) and level of GIS expertise(d).*

than people with no experience. It was important to include both experts and inexperienced map users in the experimental study, which was accomplished according to the data collected about GIS-expertise.

Chapter 4

Results

In this chapter the results of the experimental study are presented. First, an initial examination of the result is presented. Followed by a statistical analysis of quantitative data from the experiment, and a qualitative analysis of the data from the feedback section.

4.1 Initial Examination of the Results

The results for this experimental study includes the participants answers on the questions in Part 1, Part 2 and the feedback section. It does not include results form the introduction test because the participants were informed that these questions were just meant for training. Before the statistical significance test was conducted, an initial examination of the data was performed to exclude eventual outliers, and to get an overview of the data. None of the 79 participants could be identified as outliers, and all participants were therefore included in the analysis.

An overview of the percentage of correct and wrong answers for the two groups for each question is presented in Table 4.1. The overall performance was mediocre. Most of the questions have a percentage of correct answers around 50%, while some have a percentage under 20% correct answers. The question "How many earthquakes of the category catastrophic damages(red)were there in Italy?" has a very high percentage of correct answers, respectively 100% for group A and 96.77% for group B. The overall trend seems to be that the group that saw the animation with sound have a higher percentage for correct answers on the questions regarding red earthquakes. Group A saw the animation in Part 1 with sound and had a higher percentage of correct answers for both Q1 and Q2, these questions can be found in Table 4.1. The same occur in Part 2 where group B had a higher percentage of correct answers. The exception is Q5, "There was 1 earthquake of the category catastrophic damages in Russia", in Part 1, which is a "trick" question regarding an earthquake in Russia that did not appear in the animation. For the questions regarding yellow earthquakes it is difficult to find a pattern. In Part 1 Group A has a lower percentage of correct answers on Q3 than Group 2, and a higher percentage on Q4. In part 2, Group A has a higher percentage of correct answers both on Q2 and Q4. The question with the lowest percentage of correct answers was Q1 Part 2, where Group A only had 12.5% correct answers. The multiple-choice questions with alternatives True, False and Cannot tell were also designed to test the participants confidence, if they were unsure they were asked to answer Cannot tell. There is no trend indicating that the participants confidence was affected by the sound.

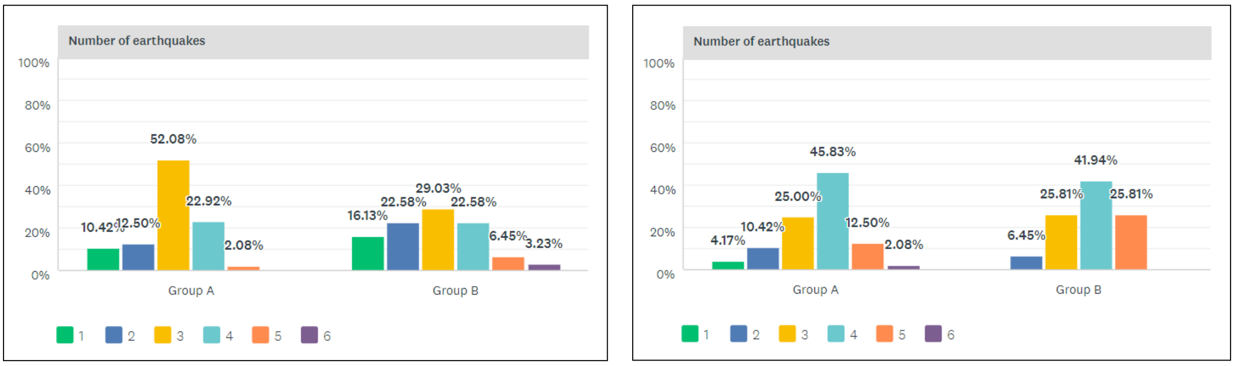
Visualizing the results give insight into the distribution of the data. SurveyMonkey provides a dashboard for analysing the results, where both visualizations and tables are presented for each question. All results of the experiment, including graphs, can be seen via a web-link[1]. The results of the first question in both parts, "How many earthquakes of the category catastrophic damages(red)were presented?", is shown in Figure 4.1. It is clear that the spread of the answers is large in these two questions, especially for group B in Part 1 and group A in Part 2, which saw the animation without sound. What is interesting is that the number of earthquakes presented, for each of the two categories, seems to have an impact on the results. The animation in part 1

[1] https://no.surveymonkey.com/results/SM-SM6N8V737/

Table 4.1: *Table presenting the results of the experiment. Percentage of correct, wrong and cannot tell answers is presented for group A and group B. Group A was shown an animation with sound in Part 1 and without sound in Part 2, and the opposite for group B.*

Part of the survey	**Questions**	**Group A answers (n=48)**			**Group B answers (n = 31)**		
		Correct [%]	**Wrong [%]**	**Cannot tell[%]**	**Correct [%**	**Wrong [%]**	**Cannot tell[%]**
Part 1	Q1: How many earthquakes of the category catastrophic damages(red) were presented?	52.08	47.92	-	29.03	70.97	-
	Q2: How many earthquakes of the category catastrophic damages(red) were there in China?	52.08	47.92	-	48.39	51.61	-
	Q3: How many earthquake of the category severe damages(yellow) were there in India?	35.42	64.58	-	45.16	54.84	-
	Q4: There was 1 earthquake of the category severe damages(yellow) in Greece	45.83	20.83	33.33	16.13	38.71	45.16
	Q5: There was 1 earthquake of the category catastrophic damages in Russia	58.33	12.5	29.17	74.19	12.9	12.9
Part 2	Q1: How many earthquakes of the category catastrophic damages(red) were presented?	12.5	87.5	-	25.81	74.91	-
	Q2: How many earthquakes of the category severe damages (yellow) were presented?	56.25	43.75	-	32.26	67.74	-
	Q3: How many earthquakes of the category catastrophic damages(red) were there in Italy?	100	0	-	96.77	3.23	-
	Q4: There was more than 1 earthquake of the category severe damages(yellow) in China	47.92	35.42	16.67	45.16	32.26	22.58
	Q5: There was one earthquake of the category catastrophic damages(red) in Papua New Guinea	64.58	16.67	18.75	83.87	3.23	12.9

contained 3 red and 13 yellow, while the animation in Part 2 contained five red and five yellow. In Part 1, the group with sound (group A), 53% answered correctly, and in the group without sound (group B) 29%. For the same question in Part 2 the group with sound (group B) 25.8% answered correctly and only 12.5% in the group without sound(group A) answered correctly.



(a) Q1 Part 1

(b) Q1 Part 2

Figure 4.1: *Results of the question "How many earthquakes of the category catastrophic damages(red)were presented?" in Part 1(a) and Part 2(b), for group A and group B. The correct answer was 3 in Part 1 and 5 in Part 2.*

Another interesting result is presented in Figure 4.2. This is question Q2, "How many earthquakes of the category severe damages (yellow)were presented?", in Part 2. The correct answer is 5, and the graph clearly show that the group that saw the animation without sound performed better than group B that saw the animation with sound. 56% in group A answered correctly while 32% in group B answered correctly. In Figure 4.3 the results from the question "There was one earthquake of the category catastrophic damages(red) in Papua New Guinea" is presented. These results indicate that the group that saw the animation with sound performed best (group B) and had a lower percentage of participants that answered "Cannot tell". The other group also performed relatively good, with a percentage of 64.6%. Results from the question "There was 1 earthquake of the category severe damages(yellow) in Greece is shown in Figure 4.4, where the correct answer was True. What is interesting is that the group that saw the animation with sound (group A) performed much better than the other group. Respectively 45.8% correct answers for group A and only 16.13% for group B.

Descriptive statistics, including mean and standard deviation for each question for the two groups, is presented in Table 4.2. The standard deviation is the average distance the participants answers were from the mean and can provide information about the spread of the data distribution. Since there were two different types of questions, the descriptive needs to be interpreted slightly different. The true/false/cannot tell questions are encoded as followed: true = 1, false = 2 and cannot tell = 3. The questions asking about the number of earthquakes had alternatives 1 to 6 with a step size of 1. The largest total standard, std.dev = 1.08, deviation can be found for Q1 in Part 1. Results for this question is shown in Figure 4.1 (a), and it clear that

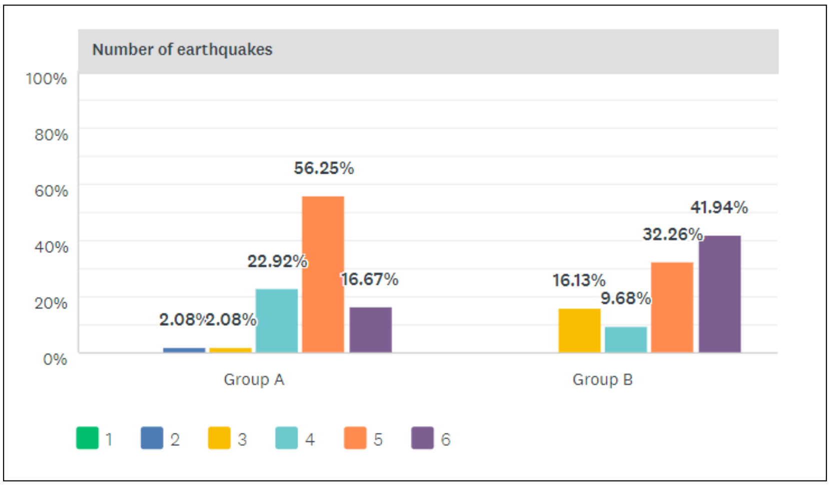


Figure 4.2: *Results of the question Q2 "How many earthquakes of the category severe damages (yellow)were presented?" in Part 2*. The correct answer was 5.

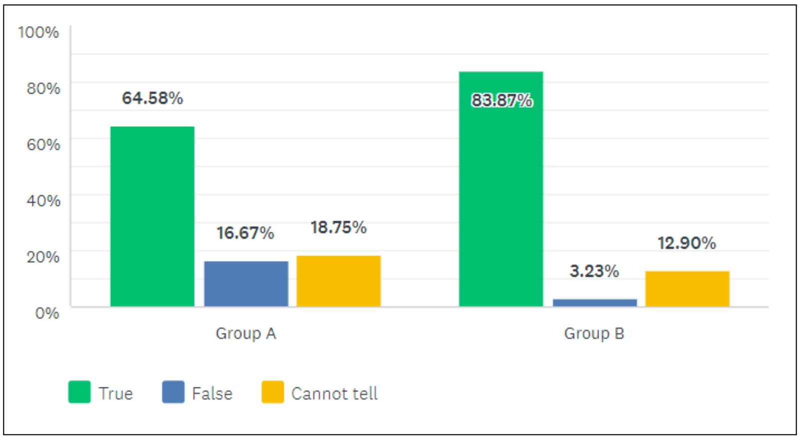


Figure 4.3: *Results of the question Q5 "There was one earthquake of the category catastrophic damages(red) in Papua New Guinea" in Part 2. The correct answer was True.*

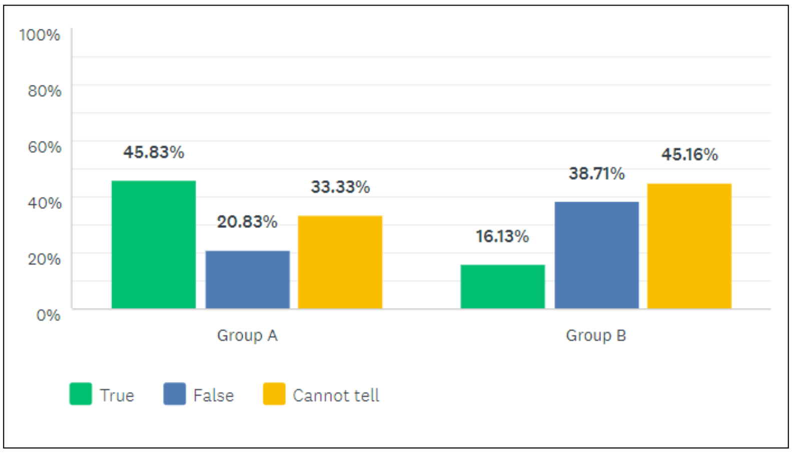


Figure 4.4: *Results of the question Q4 "There was 1 earthquake of the category severe damages(yellow)in Greece" in Part 1. The correct answer was True.*

the spread of the data is quite big, especially for group B which have a larger standard deviation. The lowest total standard deviation, std.dev= 0.11, can be found for question Q3 in Part 2. All participants except one answered this question correctly. Because of the smaller sample size in group B one incorrect answer will have a relatively larger effect on the standard deviation than for group A. Q4 part one was a true/false/cannot tell question with a relatively large total standard deviation of 0.85. The results are presented in Figure 4.4 where it is clear that the spread of the data distribution is quite large.

Part of the survey	**Question**	**Group A (n= 48)**		**Group B (n= 31)**		**Total**
		Mean	**Std.dev**	**Mean**	**Std.dev**	**Std.dev**
Part 1	Q1	2.94	0.93	2.90	1.30	1.08
	Q2	1.81	0.79	1.90	1.01	0.88
	Q3	1.90	0.83	1.71	0.74	0.80
	Q4	1.88	0.89	2.39	0.74	0.85
	Q5	2.167	0.63	2	0.52	0.59
Part 2	Q1	3.58	1.05	3.87	1.29	0.99
	Q2	4.83	0.81	5	1.1	0.93
	Q3	1	0	1.03	0.18	0.11
	Q4	1.69	0.75	1.77	0.80	0.77
	Q5	1.54	0.80	1.29	0.69	0.76

Table 4.2: *Table presenting mean and standard deviation for each group per question. In addition, the total standard deviation per question is included. Questions Q4 and Q5 in both parts of the experiment had alternatives True=1, False=2 Cannot tell = 3. Questions Q1,Q2 and Q3 had alternatives 1 to 6.*

4.2 Quantitative Analysis

A statistical significance tests was performed using IBM SPSS Statistics software[2]. The software licence was provided by NTNU. Pearson Chi-squared test for independence on the frequency for all cases, also known as Chi-squared test for association, was used to decide whether the results were statistically significant. This statistical test can be used to determine if there was a relationship between two categorical variables, in this case, to determine if the sound affected the answers of the participants. Also, it is known as a distribution-free method which fit the data given that some of the questions are not expected to have a normal distribution. Before testing for statistical significance a hypothesis-set needed to be stated:
H_0: There is no significant difference between the answers from the group that saw the animation with sound and the group that saw the animation without sound.
H_1: There is a significant difference between the answers from the group that saw the animation with sound and the group that saw the animation without sound.

[2]https://www.ibm.com/analytics/spss-statistics-software

The significance level was set to $\alpha = 0.05$, meaning the null-hypothesis was discarded if the P-value was lower than 0.05. The questions regarding the number of earthquakes all had 6 alternatives, meaning some of the alternative could contain less than 5 counts which is required for a chi-squared test. This was tested and, as expected, the 6 questions regarding number of earthquakes had alternatives with a frequency lower than 5. Therefore, a Fischer Exact test with the same significance level, $\alpha = 0.05$, was conducted on these questions. The Fisher exact test can also be used for testing association, but for a small sample size.

The results of the statistical significance test can be seen in Table 4.3. The table presents the statistics value and P-value for all question and states whether the results were statistically significant. Two of the questions, Q4 in Part 1 and Q2 in Part 2, were verified as statistically significant and the null-hypothesis was rejected. This explicitly states that there was an association between the use of sound and the answers of the participants in the two question. Q4 in Part 1, ”There was 1 earthquake of the category severe damages(yellow)in Greece”, had a higher percentage of correct answers for group A (sound). Q2 in Part 2, ”How many earthquakes of the category severe damages (yellow)were presented?”, had a higher percentage of correct answers for group A (no sound). Both Q4 and Q2 were questions about the category severe damages(yellow) which were not associated with the sound variable. Another question that had a p-value close to the significance level was Q5 in Part 2, ”There was one earthquake of the category catastrophic damages(red) in Papua New Guinea”. In this case the group that saw that animation with sound, group B, performed better.

Part of the survey	**Question**	**Pearson chi-squared**		**Fisher Exact test**		**Statistically significant**
		Value	**P-value**	**Value**	**P-value**	
Part 1	Q1	-	-	6.470	0.218	No
	Q2	-	-	2.312	0.843	No
	Q3			1.532	0.719	No
	Q4	7.718	0.023	-	-	Yes
	Q5	2.923	0.232	-	-	No
Part 2	Q1	-	-	13.555	0.004	Yes
	Q2	-	-	3.752	0.572	No
	Q3	-	-	1.891	0.392	No
	Q4	0.496	0.868	-	-	No
	Q5	4.349	0.091	-	-	No

Table 4.3: *Table presenting the results of the statistical analysis of the answers in Part 1 and Part 2. A Chi-squared association test was performed on all questions with a count larger than five for all alternatives. Fisher Exact test was performed on the questions with alternatives with a lower count than 5. Statistically significance was decided by comparing the P-value with a significance level of 0.05.*

4.3 Qualitative Analysis

In the feedback section of the experiment the participants were asked questions about the level of difficulty of the test, if they had any technical issues, if they followed all instructions, what they thought about the use of sound in map animations, and if they had any comments about the experiment. These questions were meant to give an additional level of information and to gain some insights in the participants overall experience with the test. The results of these questions will be an additional source for suggestions for further work. Analysing these types of qualitative questions is challenging, primarily since all questions and answers were written in Norwegian. Most qualitative analysing tools do not provide textual analysis of text written in Norwegian. Therefore, the analysis of the open-ended questions was done manually.

Level of Difficulty

The first question in the feedback section was ”On a scale from 1 to 10 (where 10 is very difficult) how difficult did you think the test was?”. In addition to the results from the experiment, this question provides information on how difficult the participants found the experiment. The mean value was 7.5 for group A and 7.2 for group B. This score is considered as quite high, meaning the participants found the test difficult.

Technical Issues and Instructions

Questions regarding technical issues and following instructions were added to reveal errors for individual participants, and to get feedback on the design of the web-experiment. Transcription of the comments can be found in Appendix B. Very few participants had technical issues; only 5 answered yes on the question. One participant had troubles loading the questions after the animation in Part 2, but after some patience the page loaded and everything worked fine. The rest had comments about the design of the experiment and the map animation. They complained about the video of the animation being too small, the map being too dark and the text being to small. Overall, the answers to this question did not lead to any participant being discarded. The question asking the participants if they followed all given instructions was designed to play on the participants conscience, in order to reveal any ”cheating” on the test, especially if they saw the animations several times. Three participants answered yes. One participant admitted to seeing the first animation twice and was discarded from the experiment. The two others admitted to guessing on one question and to having trouble focusing on the whole map. These errors were not considered significant errors, and the participants responses were included in the experiment.

Use of Sound in Map Animations

The question "What do you think about the use of sound in map animations?" was designed to reveal what the participants thought about the use of sound in map animations. The majority of the participants answered that sound help emphasizing specific events, which is recognisably presented in Figure 4.5, which is a visualization of the answers. What is interesting is that there are some differences between the groups. While 90.32% of group B agree on the answer saying that sound helps, 75% of group A says the same. 8.33% of the participants in group A says sound makes no difference, while 3.23% agrees with this in group B. In group A 8.33% says sound takes away the focus from other elements, while none in group B agrees on that. Some of the participants thought sound was a distraction, accordingly 4.17% in group A and 3.23% in group B. Lastly, 3.23% in group B and 4.17% in group A says sound was confusing.

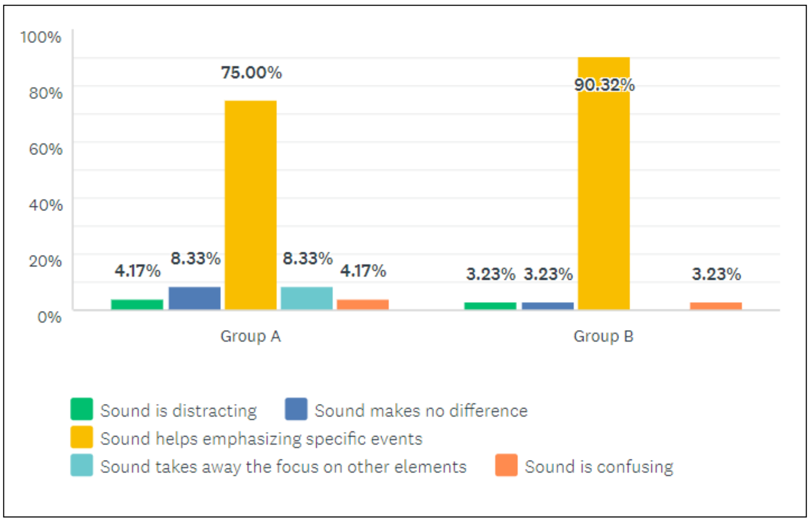


Figure 4.5: *Participants answers to the question "What do you think about sound the use of sound in map animations?"*

Comments About the Web-experiment

To add an optional comment field at the end of an experiment, which enables the participants to give suggestions for improvements or complaints, is common practice. These types of comments cannot be compared with a proper qualitative research, because they often tend to be be short and without structure. However, feedback comments can provide valuable information about the participants thoughts about the experiment. The comments are important for improving the research and will often lead to suggestions for further work.

26 of 80 participants chose to leave a comment, which can be read in full detail in Appendix B. Most of the comments were constructive feedback on the experiment design and the design of the map animation, except a few comments saying it was a cool experiment that was fun to participate in. Some of the comments gave insights into what the participants thought about the use of sound in map animations. Six of the comments said sound helped, two felt the

sound took away the focus from other elements and two thought it was hard to catch the yellow earthquakes without sound. The majority of the comments were constructive feedback on the map animation. 2 participants said the extent of the map was too big, and it was hard to decide were to focus. Five comments complained about the speed of the animation; they felt it was too fast and that they missed several events. Other comments about the design of the map animation were; the text was hard to see, the map was too dark, the borders were unclear, events appeared under the text, and the dots disappeared too fast. Regarding the design of the experiment some of the participants felt too much information was presented in very little time; it was hard to decide what to focus on, and they lacked confidence in their answers. One comment said that this experiment most likely tested the participants' memory instead of the effect of the sound. In addition, the size and length of the videos of the map animations was a problem, it was too small and too short. Inferred from the constructive comments and direct suggestions for improvements from the participants, suggestions for improvements for the research are presented in the list below:

- Lower the speed of the animation.
- Use a lighter colour on the background map and make text and borders more clear.
- Add a different sound variable for the earthquakes that caused severe damage (yellow).
- Present the animation in full-screen mode.
- Reduce the extent of the map, only focus on specific areas.
- Sound should appear earlier.
- Add 0 as an alternative for the number of earthquakes.

Chapter 5

Discussion & Conclusion

In this chapter the results of the experimental study are discussed. In the end, a conclusion and suggestions for further work are presented.

5.1 Discussion

5.1.1 Sound

Two out of the ten questions were found statistically significant, meaning that there was a significant difference between the answers from the group that saw the animation with sound and the group that saw the animation without sound. The question ”There was 1 earthquake of the category severe damages(yellow)in Greece” was one of the two. This question was quite difficult since the yellow earthquake in Greece appeared at the same time as two other earthquakes in China(one red and one yellow), and there is a considerable distance between the two countries. The group that saw the animation with sound performed better than the group without sound, with a difference of 29.7%. One explanation for this difference can be that sound helped to reduce the split attention by alerting the participants that something was going to happen. By adding sound to the red earthquakes another level of information was presented, and allows for the participants to focus on the other elements as well. The group without sound may have struggle noticing where all the three earthquakes appeared, the animation might be too complex. Harrower (2003) state that if the animation is too complex the users will struggle to decide where to focus, which will cause split attention.

The other question that had a statistically significant difference between the two groups was ”How many earthquakes of the category severe damages(yellow) were presented?”. For this question the group without sound performed better with a percentage difference of 24%. In Part 2, the distribution of red and yellow earthquakes was 50/50. A possible explanation for the significant difference between the two groups could be that the sound took away the focus from the yellow earthquakes. The group that saw the animation with sound probably was lead to focus on the red earthquakes, and had troubles paying attention to the others. This was expected, and therefore it was important to verify that you should be careful using sound as attention grabbers. The finding is supported by Harrower (2003) that state the importance of not overdoing attention grabbers. Highlighting specific events can draw attention away from other elements.

The results of the two statistically significant questions contradict each other. One indicating that sound lead the attention to other elements as well as the red earthquake, the other indicating that sound draws the attention away from other elements. Cognitive load theory can help explaining this contradiction. For the specific sequence where three earthquakes appeared at the same time the intrinsic cognitive load is expected to be high. Intrinsic cognitive load is dependent on the users ability to isolate elements, indicating that a higher complexity of the task will increase the intrinsic cognitive load(Sweller et al., 1998). In this case it seems like the sound variable helped reducing the intrinsic load by offloading work to another sensing channel, given that the group with sound performed better. To explain the other case, where the group without sound performed better, the germane cognitive load plays a part. Germane cognitive load reflects the participants effort in engaging with the material(Sweller et al., 1998). In the broader context it seems like the sound draw away the attention from other elements, and that the activity the group with sound focused on was the red earthquakes. This indicate that sound function as a attention grabber for specific tasks, but draw the attention away form other elements in a broader context.

None of the other results was found statistically significant, but there were some interesting trends. Before the experiment was conducted a hypothesis was stated, saying that the group that saw the animation with sound would perform better than the group without sound on the questions regarding red earthquakes. Some of the results indicate that this occurred. On both questions regarding the number of red earthquakes the group that saw the animation with sound performed best, which indicate that the sound enhanced the effectiveness of the map animation. Making the animation mutimodal can provide an additional level of information, which are processed separately via different channels(Mayer and Moreno, 2003). It does not reduce the cognitive load, but increases the working memory capacity(Harrower, 2007). The multimodality may have allowed the group with sound to memorize the number of red earthquakes just by hearing the alerts. However, the spread of the data distribution and the calculated p-values were quite large, which impose uncertainty of the results. Regarding the questions about yellow earthquakes, group A performed better on all questions except the first, and it is therefore not possible to tell if the sound made a difference. One explanation can be the difference in the distribution of the two categories of earthquakes in the two animations. While the first animation presented 13 yellow and 3 red earthquakes, the second animation presented 5 of each. It is possible that the number of yellow earthquakes was too high compared with the red, and that the participants unconsciously put most of the attention on the red earthquakes, while it was easier to focus on both categories in Part 2. Group A saw the animation in Part 2 without sound, and performed better on all the questions regarding yellow earthquakes. This supports the statement saying the sound may take away the focus of other elements.

The question with the smallest p-value (p= 0.091) except the ones that were found statistically significant was ”There was 1 earthquake of the category catastrophic damages(red) in Papua New Guinea”. This question can be considered as difficult since Papua New Guinea is a country very few Norwegians knows the location of, and because its location in the lower right corner would be hard to spot. However, the percentage of correct answers were high for both groups, where the group with sound performed best. This indicates that the sound did draw the users attention to the earthquake, which is supported by a comment saying that the sound was the only reason the event was spotted. An explanation for the high percentage for both the groups is that this earthquake appeared first in the animations, and was the only event that occurred at the time. Another question that stands out as very interesting is ”How many earthquakes of the category catastrophic damages(red)were there in Italy?". All participants except one answered this question correctly. There are two possible explanations for this result. First, it was expected that most of the participants would have more interest in earthquakes that appeared close to home. Italy is a country that most people in Norway are familiar with and it is a European country. Second, the red earthquake in Italy was the last event that appeared in the animation in Part 2 and people tend to remember the last thing they perceive best. On one of the questions regarding red earthquakes the participants that saw the animation without sound performed best. This question asked if a red earthquake appeared in Russia, which never occurred in any of the animations. The question was designed to test if the participants were able to separate what was presented and not in the animation. Respectively 58% in group A(sound) and 79% in group B(no sound) answered this correctly, which is a relatively high percentage of correct answers. The interesting thing is that group A had a higher percentage of cannot tell answers, which impose that these participants were unsure about the answer. It would be expected that the group that saw the animation with sound would be more confident answering this question because their attention is supposed to be drawn to the red earthquakes. However, it seems like the focus on the red earthquakes did not help seeing the bigger picture.

The true/false/cannot tell questions can be used to get an insight into the participants confidence in the information they perceived. They were asked to answer cannot tell if they were unsure or did not know the answer to the question. Comparing the group with sound and without sound, there is no trend implicating that one of the groups were more confident, meaning the sound did not affect the number of participants that answered cannot tell. Another aspect that is interesting to look at is the level of GIS experience and the percentage of cannot tell answers. The assumption is that people with a higher level of prerequisite knowledge and skills in the field would perform better than people that have little or no prerequisite knowledge(Mayer and Mayer, 2001). However, when comparing the level of GIS expertise, the percentage of cannot tell answers and correct answer no clear trend appear. The participants that considered themselves as experts or had good experience in the field did not performe better or had a lower percentage of cannot tell answers, which goes against the assumption. Given the distribution of level of GIS expertise this result cannot be trusted. Only 6 of the participants were experts and 19 had good experience, while 54 had little or non experience.

Another aspect that needs to be taken into consideration is the possibility that the first part of the experiment worked as another learning session. It would be expected that the participants gained more confidence both on how the animation worked and the types of questions for the second part. The group that saw the first animation without sound could have been positively surprised by the sound variable, and sharpened their focus. While the group that saw the second animation without sound might have expected the sound and struggled where to put their attention. However, none of the results indicate that Part 1 worked as an additional training session.

The average percentage of correct answers does not seem to be very different in the two parts for either of the groups.

Compared to the study conducted by Hall et al. (2015) this study focused on only one functionality of sound variables. Therefore, the results are only affected by one type of sound variable and can more easily be explained. It is however, difficult to verify the effect of sound based on the lack of significant results. There are many interesting findings, but few of them can be verified. It is not necessarily the use of sound variable that caused this, but rather flaws in the design of the experimental study and the map animation.

When conducting the literature research it became clear that the subject has not been explored for some time. The most recent work on the use of sound in map animation was conducted in 2015(Hall et al., 2015). Why this is the case is difficult to explain. It may be that there have been very little verification of the positive effect of sound, and that researchers has not been bothered exploring the subject further. Nevertheless, sound is used in map animations all the time. As presented by Cybulski (2016), 38% of map animations online applies sound in some way, most of them as a temporal legend. Until now sound is used based on the assumption that it will enhance the effectiveness of map animations, but this is not verified. Therefore, it is important to conduct new research which can conclude whether sound actually enhance the effectiveness.

5.1.2 Design of the Experiment

Based on the results and the feedback from the participants it is reasonable to say that the level of difficulty of the test was too high. The average score on the question asking about the level of difficulty of the test was 7.5 (group A) and 7.2(group B). In addition, the percentage of correct answers for each question mostly was around 50%. On the other hand, if the questions were too easy it would have been difficult to test the effect of sound because the percentage of correct answers would be very high for both groups. The questions were designed to reflect analytic reasoning, but whether the questions in the experiment reflect this is yet to be answered. As stated by Hall et al. (2015), it is almost impossible to design questions that reflect each individual's analytic reasoning. People tend to focus on different things when asked to analyze a map animation. There is a possibility that the questions were too much of a simplification, and that they were not sufficient to measure the effect. Another aspect of the level of difficulty is the amount of information the participants were presented simultaneously. There is a chance that the users' attention was not drawn to the processes relevant for learning, using their cognitive capacity on processes that were unnecessary and decreased the germane cognitive load. Especially the temporal legend seemed to be either neglected or draw the focus away from the earthquakes that popped up. The temporal legend can be a distracting element that often is a cause for split attention (Midtbø, 2001).

Several flaws in the design of the map animation were pointed out in the feedback comments. Flaws in the design of the material or distractions can cause an increase in the extraneous cognitive load, and use unnecessary capacity of the working memory(Sweller et al., 1998). The most prominent complaint was that the speed of the animation was too fast. This problem was also discussed in the pilot study, and the speed was slowed down before the main experiment. Based on the results of the pilot study the speed did not seem to be a problem, but these participants got to see the animation twice unlike the participants in the main experiment that got to see it once. This probably indicate that the participants in the main experiment would have benefited seeing the animation twice, and may not have such an issue with the speed. Repetitive information is easier to remember, and as suggested by Harrower (2003) using a loop of the animation may reduce the cognitive load. However, the speed and the duration of map animations should be looked at as a whole other study area. There were other problems with the design of the animation as well. Several participants complained about the large extent of the map, the background color, the text size and the boarders. In retrospect the choice of using a black background can be criticized. A lighter background would have made the other visual elements pop out more, and the text and the borders would be more visible. The extent of the map, showing almost the whole world, made the elements on the map appear as very small and was hard to see for some participants. This indicated that the design of the map animation failed, and should have been done differently.

It was decided to conduct a web-experiment to collect answers. The experiment tool used did not have any custom options for testing of geographic applications, and therefore the animation needed to be embedded as a video. Based on the questions about technical issues and the feedback comments, there were several problems regarding the video. The most prominent flaw was the size of the video. Several participants complained that the video was too small, and one wished that it was shown in full-screen. There was no possibility for monitoring the number of times each participants saw the animation or paused it; the only thing to do was to give clear instructions and trust that the participants were scrupulous. This information would have been helpful, ensuring that the terms were the same for all participants. Seeing the animation twice would give a significant advantage answering the questions. Another big flaw in the experiment design was the function for randomly dividing the participants in two groups. Skip logic was added to ensure that no participants did not see the animation twice with or without sound. Unfortunately 17 participants were discarded, which is a large number given that the number of participants in the test was 79. On the other hand discarding these participants could have been helpful in the means of finding outliers. It is fair to believe that a participant that could not answer correctly on the question about sound in the animation would fail on other types of questions as well. A possible solution for all these problems would have been to create a custom test-tool that could monitor all interactions with the animations, provide the necessary control of the logic and that was suited for testing map animation. Because of the time scope of this thesis it was not viable to develop a tool like this. It did not seem like the participants had any troubles understanding the questions, which probably was thanks to the readjustments based on the results of the pilot study.

The target group of this experiment was all potential map reader that at some time could be presented a map animation. This is a large group of the population, and therefore a spread in age, gender, work situation and level of GIS experience is necessary for both groups in the experiment. The sample size was uneven for the two groups because of the flaw in the random division of groups and the page skip logic. In total, 17 participants were discarded from the experiment because they failed on the question about sound, most of which were in group B that saw the animation in Part 1 without sound. Therefore, only 31 participants was in group B while group A had 48. This was a sizeable possible source of error. For group B, one incorrect answer from one participant had a larger impact on the total result for the group. As an example, on the question about a red earthquake in Italy one of the participants in group B failed, which lead to 3.23% incorrect answers. It is possible that the sample size in each group was too small, and that it is not a good representation of the target group. The distribution of gender was relatively equal in both groups, with four more males in group A and one more in group B. It can be argued that this is a good representation for the population given that there are more men in the world compared to women, and that the group of map readers traditionally have consisted of more men than women. The participants age is clearly representative for the social network of the author, where two age groups stand out (18-28 and 40-65). It is not an optimal representation for all map readers; the ideal distribution would have been equal for all age groups over 18 years. Most of the participants were either students or had income-generating work, which are the groups that are most likely to be presented a map animation to analyse. For the level of GIS-expertise it was desirable to have a equal distribution of expert and persons with good experience and people with little or none expertise, this was not accomplished. There are far more participants with little or none expertise, and especially in group A. This made it hard to study if the level of GIS expertise had an impact on the performance.

5.2 Conclusion

The goal of this master thesis was to study the effect of sound variables, as an attention grabber, in map animations. This question have been discussed by geo-visulization researcher, but rarely studied. The last few years it has been very quiet in the field. Findings from research on multimedia learning and cognitive load theory indicate that the use of sound in map animations will raise the cognitive limit and enhance the effectiveness of map animations, but this is yet to be confirmed. This research was an attempt to fill a gap in the research on the effect of sound variables in map animations, but failed to provide unambiguous results.

This study focused on one functionality of sound variables, in contrast to other studies that have combined several functions at the same time. The results were not sufficient to conclude whether sound, as an attention grabber, enhance the effectiveness of map animations, but there were some promising trends. The results indicate that there is a relationship between the use of sound and the performance of the participants, but they can not be stated as significant. For most of the questions regarding red earthquakes, which were paired with the sound variable, the group that saw the animation with sound performed better than the group without sound. There was also evidence that the sound sharpened the focus of the participants when red and yellow earthquakes appeared simultaneously. However, there is evidence stating that the sound draws away the attention from other elements, in this case the yellow earthquakes. Therefore, it is important to be careful using sound as an attention grabber, do not overdo it.

There are several reasons why the results of the experiment were inconclusive and could not help answering the research questions. Based on the results and feedback comments it is reasonable to conclude that the design of the experiment was not sufficient to measure the effect, and that the level of difficulty was too high. In addition, the design of the map animation was not good enough; the participants complained about several of the visual elements in addition to the speed and duration of the animation. Concluding whether sound variables enhance the effectiveness of map animations is not possible based on this research. However, the results shows promising trends and the research should be explored further.

5.2.1 Further Work

This study produced some interesting results, but the design of the experiment was not sufficient. Both the experiment design and the design of the map animation should be improved. The main issue with the map animation was the speed and duration, which is something that should be studied in more details, separately. A suggestion for improving the experiment design is to create a custom made web-based test-tool, that provide all desirable functions for monitoring interaction, dividing participants into groups and presenting the map animation.

In this experiment only one dynamic variable was paired with a sound variable. For further research it will be interesting to look at the effect of using different sound variables for different visual variables. The information presented in the animation was repetitive, meaning both the visual and the sound variable presented the same information. Another aspect that should be studied separately is adding sound variables that present additional information. As an example the temporal legend could be replaced by sound. There is clearly work to be done exploring the use of sound in map animations. Based on results form other studies on multimedia learning and sound in map animations, and the results of this experimental study, it is yet needed to verify or discard the that the use of sound enhance the effectiveness of map animations.

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Appendix A: Copy of the Web-experiment

Following is a copy of the web-experiment that was sent out to the participants. It is written in Norwegian.

Kartanimasjon og lyd

Kartanimasjon og lyd

Denne spørreundersøkelsen gjennomføres i forbindelse med en masteroppgave i geomatikk ved Institutt for bygg- og miljøteknikk - NTNU. Formålet med spørreundersøkelsen er å studere effekten av lyd i kartanimasjoner.

Tusen takk for at du tar deg tid til å gjennomføre undersøkelsen!
Dersom du har noen spørsmål om spørreundersøkelsen er det mulig å ta kontakt på e-post: annabk@stud.ntnu.no.

Anna Bellika Kjæmpenes
NTNU- Ingeniørvitenskap og IKT- geomatikk

Kartanimasjon og lyd

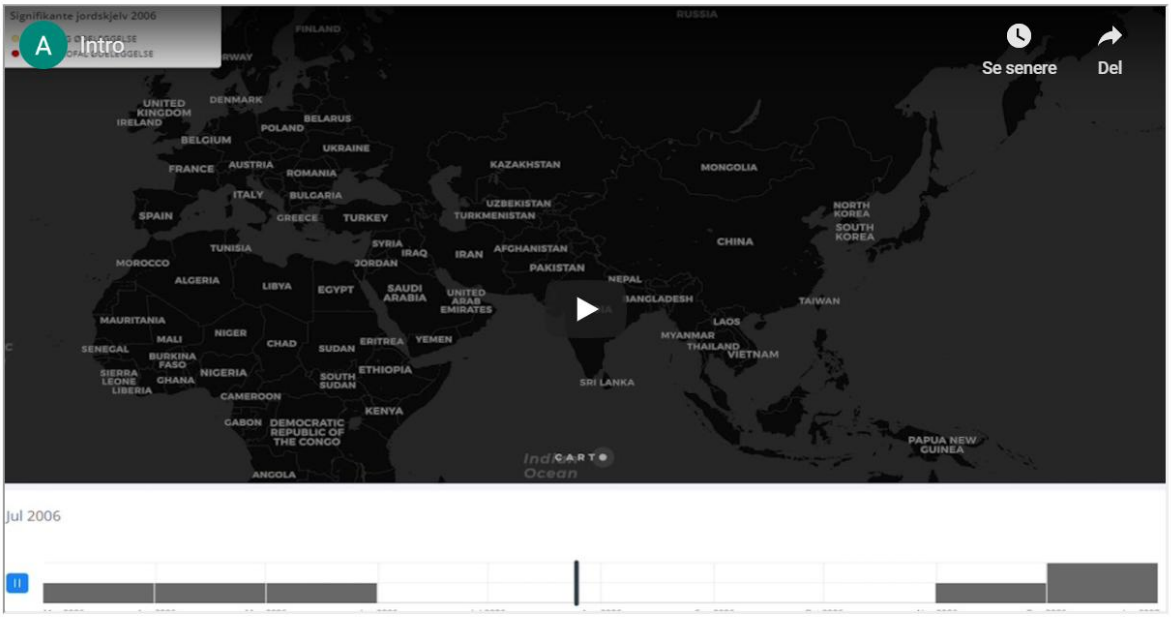
Introduksjon

Denne undersøkelsen vil ta omtrent 10 minutter. Det er viktig at du befinner deg i et rolig miljø uten forstyrrelser og at du følger alle instruksjoner som blir gitt underveis. Noen av spørsmålene inneholder lyd, så husk å sette på lyd før du begynner.

Spørreundersøkelsen vil omhandle en kartanimasjon av signifikante jordskjelv i verden. Tidslinjen nederst viser når jordskjelvene oppsto, og søylene representerer hvor mange jordskjelv det var per måned. Jordskjelvene som vises på kartet tilhører to kategorier:
Alvorlige ødeleggelser(gul)
Katastrofale ødeleggelser (rød)

Følgende er en introduksjon på hvordan eksperimentet vil foregå. Denne delen inngår ikke i eksperimentet, og er ment som en øvelse.

Du skal se videoen av animasjonen 1 gang uten pause, og deretter svare på spørsmål om det du har sett. Det er viktig at du følger godt med. Spørsmålene vil basere seg på antall jordskjelv av de to kategoriene(rød og gul) og plassering på kartet, og er eksempler på type spørmål du kan få om animasjonen.



* 1. Hvor mange jordskjelv av kategorien katastrofal ødeleggelse (rød) ble presentert i animasjonen?

	1	2	3	4	5	6
Antall jordskjelv	○	○	○	○	○	○

* 2. Det var 1 jordskjelv av kategorien alvorlige ødeleggelser(gul) i Kina

○ Riktig ○ Galt ○ Vet ikke

Kartanimasjon og lyd

Hoveddel: Eksperiment

Resterende deler av spørreundersøkelsen vil bli tatt med i eksperimentet. Det er derfor viktig at du følger alle instruksjoner, og svarer så godt du kan på spørsmålene. Husk å sette på lyd!

Forsøket vil foregå på følgende måte:
Du vil først få se en video av kartanimasjonen. Denne skal du se 1 gang uten pause. Tenkt deg at du skal analysere animasjonen og få med deg så mye som mulig av informasjonen som presenteres. Fokuser spesielt på antall jordskjelv av de to kategoriene og plassering på kartet.

Deretter skal du svare på spørsmål basert på animasjonen. Det er viktig at du ikke direkte gjetter på

svarene, men svarer så godt du kan utfra det du husker fra animasjonen. Det vil ikke være mulig å gå tilbake for å se animasjonen på nytt eller endre svar på spørsmål når du trykker neste.

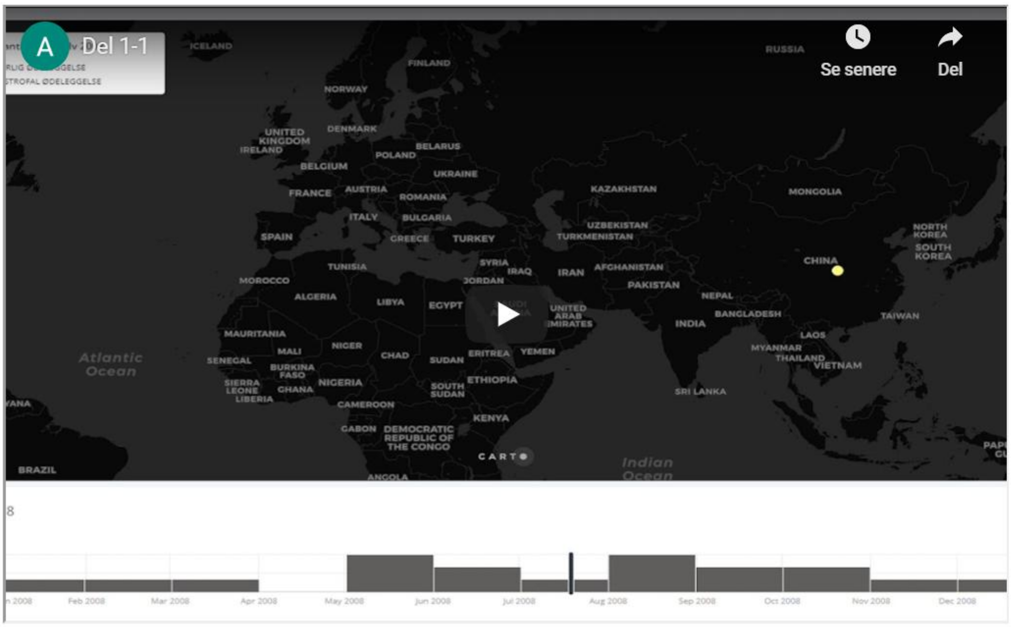
Du skal gjennomføre to deler med samme oppsett. En del vil inneholde en animasjon med lyd og en del uten lyd, med tilhørende spørsmål. Det er tilfeldig hvilken del du får først.

Kartanimasjon og lyd

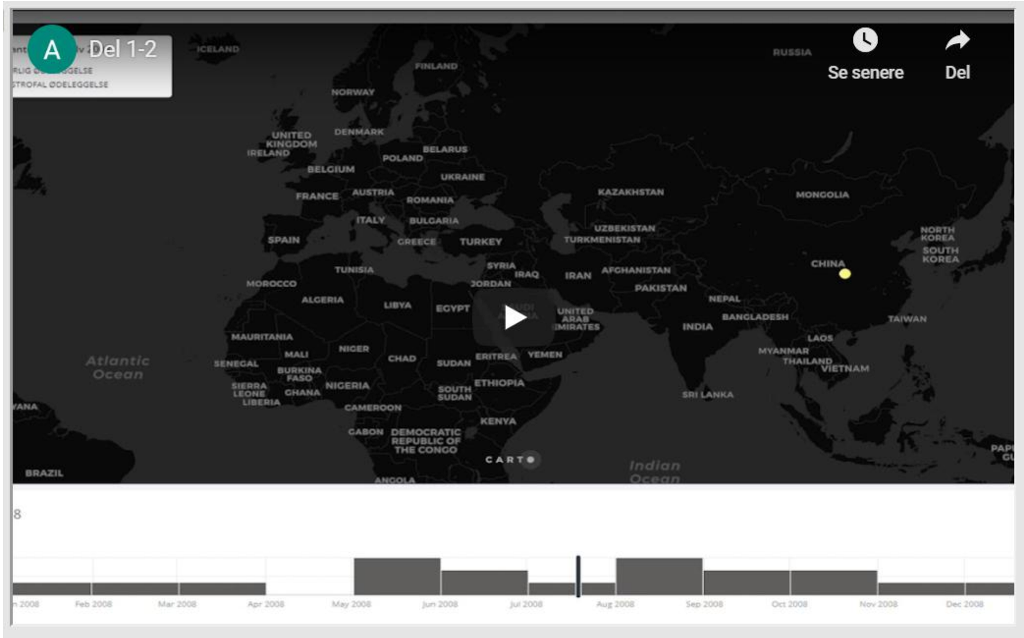
Del 1

Se videoen av kartanimasjonen 1 gang uten pause.

A 50.0%



B 50.0%



Kartanimasjon og lyd

Del 1- Spørsmål

Spørsmålene under baserer seg på animasjonen du nettopp har sett.

Kartet kan være til hjelp hvis du trenger å se hvor de ulike landene er.

* 1. Hvor mange jordskjelv av kategorien katastrofale ødeleggelser (rød) ble presentert i animasjonen?

	1	2	3	4	5	6
Antall jordskjelv	◯	◯	◯	◯	◯	◯

* 2. Hvor mange jordskjelv av kategorien katastrofale ødeleggelser (rød) var det i Kina?

	1	2	3	4	5	6
Antall jordskjelv	◯	◯	◯	◯	◯	◯

* 3. Hvor mange jordskjelv av typen alvorlige ødeleggelser(gul) var det i India?

	1	2	3	4	5	6
Antall jordskjelv	◯	◯	◯	◯	◯	◯

* 4. Det var 1 jordskjelv av kategorien alvorlige ødeleggelser(gul) i Hellas (Greece)

◯ Riktig ◯ Galt ◯ Vet ikke

* 5. Det var 1 jordskjelv av kategorien katastrofale ødeleggelser(rød) i Russland

◯ Riktig ◯ Galt ◯ Vet ikke

* 6. Var det lyd på animasjonen du nettopp så?

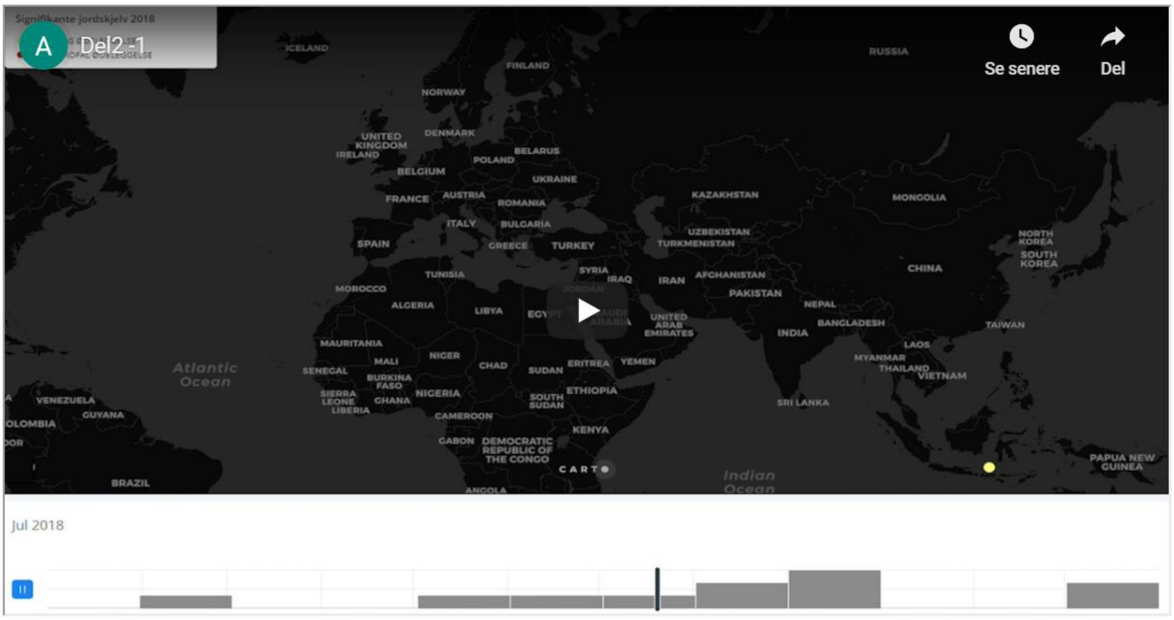
◯ Nei

◯ Ja

Kartanimasjon og lyd

Del 2

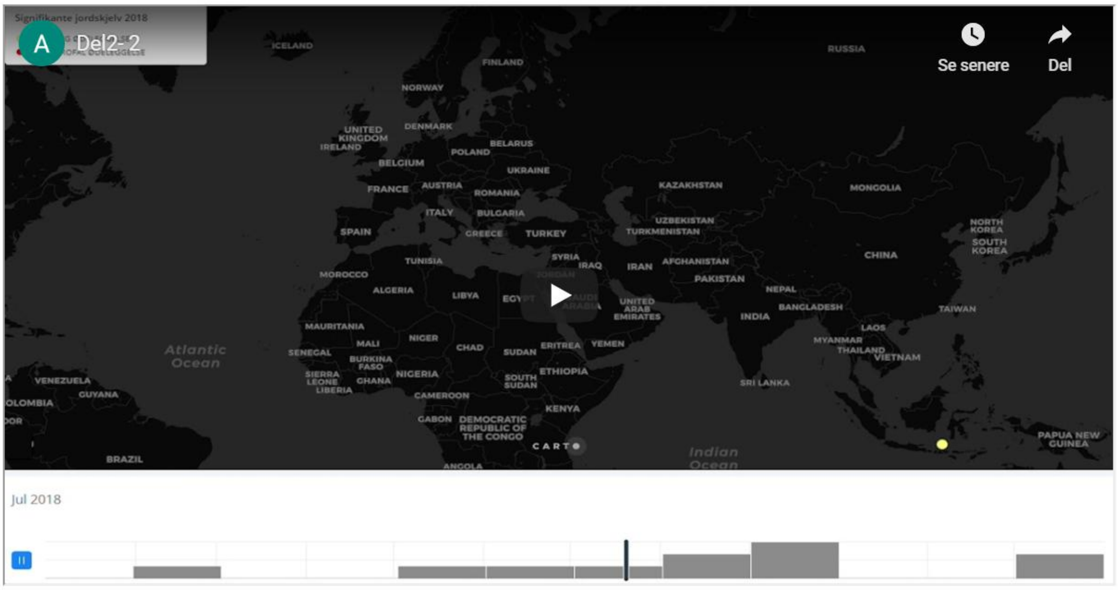
Se videoen av kartanimasjonen 1 gang uten pause.



Kartanimasjon og lyd

Del 2

Se videoen av kartanimasjonen 1 gang uten pause.



Kartanimasjon og lyd

Del 2- Spørsmål

Spørsmålene under baserer seg på animasjonen du nettopp har sett.

Kartet kan være til hjelp hvis du trenger å se hvor de ulike landene er.

* 1. Hvor mange jordskjelv av kategorien katastrofale ødeleggelser (rød) ble presentert i animasjonen?

	1	2	3	4	5	6
Antall jordskjelv	◯	◯	◯	◯	◯	◯

* 2. Hvor mange jordskjelv av kategorien alvorlige ødeleggelser (gul) ble presentert i animasjonen?

	1	2	3	4	5	6
Antall jordskjelv	◯	◯	◯	◯	◯	◯

* 3. Hvor mange jordskjelv av typen katastrofale ødeleggelser(rød) var det i Italia?

	1	2	3	4	5	6
Antall jordskjelv	◯	◯	◯	◯	◯	◯

* 4. Det var flere enn 1 jordskjelv av kategorien alvorlige ødeleggelser(gul) i Kina

◯ Riktig ◯ Galt ◯ Vet ikke

* 5. Det var 1 jordskjelv av kategorien katastrofale ødeleggelser(rød) i Papua New Guinea

◯ Riktig ◯ Galt ◯ Vet ikke

Kartanimasjon og lyd

Tilbakemeldinger

* 1. På en skala fra 0 til 10 (der 10 er veldig vanskelig) hvor vanskelig synes du spørreundersøkelsen var?

0 10

* 2. Hadde du noen tekniske problemer?

- Nei
- Ja (vennligst spesifiser)

* 3. Fulgte du alle instruksjoner som ble gitt?

- Ja
- Nei(vennligst spesifiser)

* 4. Hva tenker du om bruk av lyd i kartanimasjoner?

- Lyd er distraherende
- Lyd utgjør ingen forskjell
- Lyd hjelper til med å fremheve spesielle hendelser
- Lyd trekker fokus bort fra andre elementer
- Lyd er forvirrende

5. Har du noen kommentarer til spørreundersøkelsen?

Kartanimasjon og lyd

Informasjon om deg selv

* 1. Kjønn?

- Kvinne
- Mann
- Ønsker ikke å svare

* 2. Alder?

- Under 18 år
- 18-28 år
- 29-39 år
- 40-65 år
- Over 65 år

* 3. Hvilket av følgende alternativer passer best til din yrkesstatus?

- Student
- Yrkesaktiv, inntektsgivende arbeid
- Deltidsansatt
- Arbeidsledig eller arbeidssøker
- Pensjonist
- Militærtjeneste
- Permittert
- Foreldrepermisjon
- Uføretrygdet
- Annet

* 4. Hvilken erfaring har du med GIS(Geografiske Informasjonssystemer)?

- Ekspert
- God erfaring
- Litt erfaring
- Ingen erfaring

Appendix B: Transcription of Feedback Comments

This appendix is a transcription of all feedback on the questions about technical issues, following instructions and comments about the web-experiment. The original answers are written in Norwegian and are translated to English.

Question: Did you have any technical issues? No/yes(please specify)

No: 75

Yes (Please specify): 5

#1: Between the video in part 2 and the questions the web-page, was loading. It took a very long time before the questions appeared.

#2: The map was small, and it was hard to see which country the dots appeared in. It was easier to see the continents-after a while.

#3: The text size was too small, the map was too dark

#4: Yes, in the sense that I wish the map had been bigger. It was a little distracting that the names of the countries were so small, that drew my attention away from focusing on the number of earthquakes.

#5: No sound on the first video

Question: Did you follow all given instructions? No/yes(please specify)

No: 77

Yes (Please specify): 3

#1: I saw the first video 2 times

#2: I guessed once. It was too tempting to not just answer “Cannot tell”.

#3: I could not focus on the entire map. It was hard to memorize the yellow dots.

Question: Do you have any comments regarding the survey? Text field

This question was optional.

No: 54

Yes: 26

#1: I felt that counting the number of yellow dots could require all the focus, the number of red dots was difficult, and I could not keep track of the location of the dots at all.

#2: It went to fast

#3: It was a little difficult to catch all the yellow dots without sound, but I suppose the focus should be on the red dots. Maybe use a different sound for the yellow dots?

#4: Cool experiment. Sound definitely set the focus when you should pay extra attention, but I don't really understand how this will be used in practice.

#5: The map was not good for seeing where things are, it should have been in full screen.

#6: The symbols are not particular prominent in such a big map. Could not focus on the whole map at the same time, its easy to miss a small dot.

#7: Hard to memorize information based on one short video. The sound may have helped register that an event occurred. Different sound for severe damage and catastrophic damage could have been something that would help.

#8: It was fun to participate.

#9: Your attention is focused on what is presented with sound. Whether the events that don't have sound are easier or harder to perceive when it is emphasized with sound will be exciting to see.

#10: Keeping track of how many earthquakes, in which category AND where they were is too much information presented. A sound which in addition is the same for both red and yellow is incorrect for displaying the category. But it is ok to use sound to signal that a new earthquake appears in the map

#11: Hard to remember the number of events without the sound.

#12: I have a suspicion that this experiment tests the memory more than it tests the use of sound. It was very difficult paying attention to and remembering all the dots when the animation was so fast, independent of sound.

#13: Hard to see the text on the map on a laptop.

#14: Hard to see when it was a black background with small white letters.

#15: The information in the maps were presented very quickly. Therefore, it was hard to count the number of earthquakes at same time as paying attention to which countries they appeared in. It was also confusing that the types of questions were different in the two parts. In Part 1 I got no question about the total number of earthquakes, while in Part 2 I got this question. I shifted the focus on what I should look for (counting number or remembering countries) between the two parts.

#16: Nope

#17: Nicely done. Hard to remember many different types of information at the same time. If you concentrate on counting it is impossible (for me) to remember more than a couple of countries.
#18: Occasionally difficult to locate events, as the cursor was under the country name. As an example, I struggled finding a red dot under Papa New Guinea. The sound helped alerting me that there was something to look for.
#19: Could the sound appear earlier?
#20: It went to fast. Fun, but difficult to see the precise borders.
#21: It was easier to catch the catastrophic damages with sound, but it can take away the focus from other things.
#22: 0 as an alternative for number of earthquakes could have been included.
#23: I thought it was close to impossible to keep up. The map was to small and it was hard to catch which countries the red and yellow dots appeared in. The biggest challenge for me was the speed of the animation. When I had to see which country the dots appeared in, or looked at the timeline, new dots appeared and where did they appear? It went way too fast, and the map was to small that I got the opportunity to answer qualified. It reminds me a little of a TV-quiz where gymnastics with different colors and runs around. Then questions like how many yellows came from the right, was it more than 5 red. The excitement of this quiz is if the participant has a well-developed sense of catching and remembering things form an information stream. I think that there is a good possibility that you can remember more if the speed is lowered, and if the map is made clearer which will make it easier at decipher. I don't really think I got many correct answers, if any.
#24: Very short videos which made it hard to catch what was presented.
#25: It vent too fast.
#26: A list should appear under, where for example color and land was enlisted, so that the events did not disappear so fast.

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