Utrecht University

Department of Information and Computing Sciences

Human-Computer Interaction - Master Thesis

"Why Are You Doing This?"

Identifying Lifeloggers Motivation and Behaviour in Order to Improve Simulated Search Tasks.

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Abstract

A lifelog is a unified digital record of the life of one person. Lifeloggers continuously capture personal data in a multi-modal manner to expand their digital record. An example of such data is lifelog images. These images are captured continuously using body cams and stored for future use. Despite the increasing popularity of lifelogging, it is unknown why people practice it, how they use their data, and how they search through it. These knowledge gaps must be filled to support future work for the development of lifelog search and storage systems. Academic competitions such as the Lifelog Search Challenge, where researchers gather to evaluate their lifelog systems via simulated search tasks, would highly benefit from answers to these questions. This research addresses these issues in a series of surveys and interviews with end users and researchers. In particular, the behaviour and needs of lifeloggers are researched via online surveys. Options for simulated search tasks are researched via online surveys, semi-structured interviews, and a review of academic events. Despite a rather low response rate for the online survey for lifeloggers, the results indicate that their main motivation is fun, they use their data for reminiscence, they want searching through their data to be easier, and they search for both specific images and other information. The online surveys and interviews with lifelogging researchers and event organisers identified numerous potential improvements for evaluation of search systems: the data set should be expanded with more data and more lifeloggers, the focus should be laid more on the novices that test the systems, the variance caused by the novices should be decreased, the query descriptions should be made less ambiguous, and a second search task should be introduced. The combination of the information about the needs of the lifeloggers combined with the insights gained from the lifelogging researchers confirms that the research in this field is going in the right direction and provides concrete aspects to improve it.

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Contents

Preface

This thesis, entitled *Why Are You Doing This? Identifying Lifeloggers Motivation and Behaviour in Order to Improve Simulated Search Tasks*, investigates the motivations and behaviour of lifeloggers and the simulated search tasks with which lifelog search systems are tested and evaluated. It was written to fulfill the graduation requirements of the MSc Human Computer Interaction programme at Utrecht University. The thesis is divided into two parts: the scientific paper and the annotated appendix. The initial goal was to write a publishable scientific paper and an annotated appendix that covers everything that could not be included in the scientific paper. This lead to the creation of the following deliverables during this thesis:

- A scientific paper, which can be found in Part 1 of this document.
- An annotated appendix, which can be found in Part 2 of this document. It provides a more in-depth look at some elements that are only briefly covered in the scientific paper such as:
  - A detailed literature review covering the subjects of lifelogging, lifelog data usage, and lifelog search systems.
  - An in-depth review of academic events, the tasks used during these events, and the trends that were identified following the review.
  - The surveys, interview questions, and consent forms used during this study.

Ruben van Ettinger
Heemskerk, July 11, 2021

PART I

Scientific Paper

"Why Are You Doing This?" Identifying Lifeloggers Motivation and Behaviour in Order to Improve Simulated Search Tasks.

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***Abstract*—A lifelog is a unified digital record of the life of one person. Lifeloggers continuously capture personal data in a multi-modal manner to expand their digital record. An example of such data is lifelog images. These images are captured continuously using body cams and stored for future use. Despite the increasing popularity of lifelogging, it is unknown why people practice it, how they use their data, and how they search through it. These knowledge gaps must be filled to support future work for the development of lifelog search and storage systems. Academic competitions such as the Lifelog Search Challenge, where researchers gather to evaluate their lifelog systems via simulated search tasks, would highly benefit from answers to these questions. This research addresses these issues in a series of surveys and interviews with end users and researchers. In particular, the behaviour and needs of lifeloggers are researched via online surveys. Options for simulated search tasks are researched via online surveys, semi-structured interviews, and a review of academic events. Despite a rather low response rate for the online survey for lifeloggers, the results indicate that their main motivation is fun, they use their data for reminiscence, they want searching through their data to be easier, and they search for both specific images and other information. The online surveys and interviews with lifelogging researchers and event organisers identified numerous potential improvements for evaluation of search systems: the data set should be expanded with more data and more lifeloggers, the focus should be laid more on the novices that test the systems, the variance caused by the novices should be decreased, the query descriptions should be made less ambiguous, and a second search task should be introduced. The combination of the information about the needs of the lifeloggers combined with the insights gained from the lifelogging researchers confirms that the research in this field is going in the right direction and provides concrete aspects to improve it.**

Keywords: Lifelogging, search behaviour, data usage, search tasks, search system evaluation

1. INTRODUCTION

Lifelogging is the practice of continuously capturing personal data. A large amount and variety of data can be captured while lifelogging. Examples of such data include images, video, audio, GPS coordinates, accelerometer data, heart rate, steps taken, calories consumed, etc. Lifelogging has existed in some shape or form for thousands of years ever since people started recording their lives using diaries. However, the current idea of lifelogging has deviated strongly from the practice of keeping a diary. The rise of modern technology such as digital cameras, smartphones, and computers with the capability of storing huge amounts of data for a relatively low price has transformed lifelogging into a practice of (automatically) capturing many kinds of data instead of just one's thoughts. Especially the invention of small, wearable devices that can capture images, video or audio has increased interest in lifelogging enormously. As of right now, there is not one central definition of lifelogging. This study uses the following definition by Dodge and Kitchin [1]:

> A form of pervasive computing, consisting of a unified digital record of the totality of an individual's experiences, captured multimodally through digital sensors and stored permanently as a personal multimedia archive.

Because of technological advancements and an increased interest, lifelogging has become an active field of research [2]. Related research covers many different aspects of lifelogging with examples such as privacy, information visualisation, browsing lifelog images using virtual reality, etc. One such research direction investigates lifelog search systems. A huge challenge of lifelogging is dealing with lifelog image archives that can easily contain tens of thousands of images. Some lifelog image archives even contain millions of images like that of the lifelogging researcher Cathal Gurrin [3]. These image archives can quickly grow out of hand and become impossible to browse through or find things in. For this reason, many researchers are developing different lifelog search systems. This has culminated in international initiatives to objectively evaluate and assess these lifelog

search systems. An important example of such an initiative is the Lifelog Search Challenge (LSC) [4] which is held annually as part of the ACM International Conference on Multimedia Retrieval (ACM ICMR) [5]. Participants of the LSC develop a lifelog search system to find the answers to known-item search tasks. These search tasks simulate real searches that could be conducted by actual lifeloggers. However, it is challenging to realistically simulate lifelog search tasks for a number of reasons. First, lifelog data is quite different from other data, and there is little knowledge about the most common information needs and any other reasons people want to access it. Moreover, there is little research on how related search strategies and approaches are commonly applied by lifelog users. Finally, lifelog data is very personal, which has a huge impact on the used search strategies and the motivations behind them, and also makes it very difficult to do large-scale objective evaluations. The aim of this research is to analyse search motivations and strategies in order to improve realistic simulations of search tasks in an objective evaluation. A secondary aim is identifying the motivations and wishes of lifeloggers to gain deeper insight to improve future interface and interaction design for lifelog data searching and browsing.

In this work we investigate the aspects of lifelog motivation, data usage and search behaviour in order to improve simulation and testing of search tasks and to specify better guidelines for future design of lifelog software. These aspects have been chosen because they are interconnected. It is not possible to investigate the search motivation of lifeloggers without knowing their motivations behind lifelogging or their behaviour regarding their data usage, which is why our aim is to fill these knowledge gaps. An example of such a knowledge gap is that it is not known why lifeloggers practice lifelogging or what lifeloggers do with their lifelogging data. The data used to fill these gaps results from online surveys and semi-structured interviews. The target participants for these are lifeloggers, GoPro users, and lifelogging researchers and organisers of the LSC.

The paper is structured as follows: Section 2 covers background information and related work regarding the topics of lifelogging, data usage, and lifelog search systems. It analyses current research and identifies the knowledge gaps that still exist. These knowledge gaps are the basis for the objectives described in Section 3. To fill these knowledge gaps and achieve the objectives the methodology is introduced in Section 4. The results are then covered in Section 5 and are discussed further in Section 6 along with the limitations of the study. Finally, Section 7 provides conclusions regarding the research questions and proposes recommendations for future work.

2. RELATED WORK

2.1. Lifelogging

Lifelogging and lifelog image capturing have existed in their current shape ever since the Microsoft SenseCam was patented in 2009 [6], although research on lifelog image capturing has been conducted as early as the 1980's [7]. It has evolved into its current shape with the increasing availability and dropping costs of modern technology. This allows the everyday user to acquire and use wearable cameras and cheaper data storage, making lifelog image capturing an easier task. Despite the relative ease of lifelogging and the increased interest in the field, little research has been conducted regarding the lifeloggers themselves. As of yet, the major motivations why lifeloggers practice lifelogging are unknown, although research has found some reasons why non-lifeloggers would start lifelogging [8] or why non-lifeloggers create life-long collections of memories [9]. It is currently unknown if these findings apply to lifeloggers as well or if lifeloggers have different or additional reasons behind practicing lifelogging. One of the aims of this study is to investigate this. Achieving this aim will make it easier to provide more suitable services to lifeloggers in the future.

2.2. The Quantified Self

There is one motivation behind lifelogging that is currently known: a phenomenon called the *quantified self*. This term has been coined by Wolf and Kelly [10] in 2007 and is defined as:

> a collaboration of users and tool makers who share an interest in self knowledge through self-tracking

As stated in the definition, *gaining self knowledge* is a motivation of people interested in the quantified self. Gaining this self knowledge is done through self-tracking. The concepts of self-tracking and lifelogging overlap and can be used interchangeably. Therefore, gaining self knowledge can be seen as one of the motivations behind lifelogging. However, it would be useful to discover how many lifeloggers consider this a motivation to provide an indication of the importance of the quantified self to lifeloggers.

Choe et al. have conducted research regarding the motivations of so-called *quantified-selfers* and have split the motivations into three main categories [11]:

- To improve health
- To improve other aspects of life
- To find new life experiences

One characteristic that sets the quantified self apart from lifelogging in terms of focus is tracking health related data. While it is not uncommon for lifeloggers to track data like heart rate or caloric intake, the quantified self community is much more focused on this. Therefore, we can not just assume that lifeloggers share the motivations found by Choe et al. with quantified-selfers.

2.3. Lifelog data usage

Lifelogging is more than just the capturing of lifelog images using a lifelog camera. In reality, there are many different types of data that can be captured when lifelogging. Machajdik et al. provides a list [12]:

- Passive Visual Capture (images captured using wearable, "always on" cameras)
- Biometrics (heart rate, galvanic skin response, skin temperature, body motion)
- Mobile context (GPS data, wireless network presence, GSM location data)
- Mobile activity (Call logs, SMSes, email-logs, web activity, social network activity)
- Desktop/laptop computer activity (All computer activity, saved documents)
- Active capture (written blogs, actively taken pictures)

Collecting large amounts of data results in a lifelog data archive quickly growing too large to use or browse through. This is especially true for lifelog images as passively capturing an image each minute would result in 1440 images captured in one day. While not every image would be unique and interesting to look at it is still quite cumbersome to browse through. Even a casual user who only wears his camera one day a week would quickly collect a lifelog image archive containing tens of thousands of lifelog images. It is currently unknown what lifeloggers do with these captured lifelog images or what they would do with them given the opportunity. Previous research mentioned earlier covers this subject and has identified a number of common, overlapping data usages among non-lifeloggers [8] [9]:

- Boosting memory
- Re-telling stories
- Keeping things for potential later use
- Saving things for sentimental value
- Keeping family memories

These studies do not confirm if lifeloggers share these same data usages with non-lifeloggers. Another aim of this study is to investigate if these data usages apply to actual lifeloggers and if the known usages are still up-to-date. It is not unlikely that they could have changed in recent times due to changing technology.

2.4. Lifelog search systems

Working with the amount of data produced by lifelogging is difficult, especially when it comes to the huge lifelog image archives. This is why researchers are developing lifelog search systems; to support the lifeloggers during their search. These search systems are tested and evaluated during academic events such as the LSC. The third edition of the LSC, LSC'20, featured 14 different lifelog search systems from 11 countries.

The first iteration of the LSC in 2018 was won by the Virtual Reality Lifelog Explorer, a lifelog search system with a virtual reality (VR) interface developed by Duane et al. [13]. One of their research goals was to examine the potential of VR interfaces to interact with lifelog data as they believe that VR will become widespread in the near future. The user creates queries using two sub-menus to select different tags and the temporal aspect of the query. The tags sub-menu is shown in Figure 1. This results in queries such as "using the computer on a Saturday afternoon". The querying interface then disappears and the ranked results are shown in a decreasing rank order, which means that the first image shown fits the query the best. While the VR interface produced no increase in efficiency over conventional interfaces, there were no notable drawbacks.

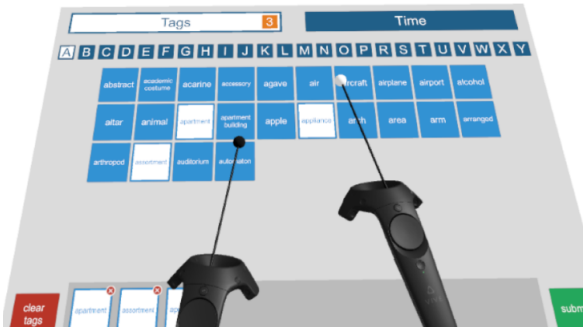

Figure 1. The tags sub-menu of the Virtual Reality Lifelog Explorer

The LSC in 2019 was won by vitrivr, which is a content-based multimedia retrieval stack developed by Rossetto et al. vitrivr was initially developed to participate in the Video Browser Showdown (VBS), an academic event that served as the inspiration for the LSC. As the VBS features a known-item search task similar to the one featured in the LSC, the vitrivr system could be applied to a lifelog retrieval setting without much difficulty. The system allows users to search using different querying methods such as Query-by-Sketch, Query-by-Example, and Relevance Feedback. These methods allow users to sketch a scene from their memory (QbS), to create a query using one of the image results (QbE), or to mark results as relevant or non-relevant to find similar images deemed to be relevant (RF). The existing vitrivr system was expanded to handle the *image sequence* data type, which are the lifelog images in the LSC data set. Despite not being built for the LSC and with only minor changes made, the vitrivr system still managed to win the 2019 edition of the LSC. [14].

As mentioned, the 2020 edition of the LSC featured 14 lifelog search systems from 11 countries. Due to the COVID pandemic at the time, the event was held virtually rather than physically. One example of a system participating in this edition (and all previous editions) is the lifeXplore system [15]. Just like vitrivr, lifeXplore was initially developed for the VBS. The system participated in several editions of the VBS under the name diveXplore, which stands for *distributed interactive video exploration* [16], before being adapted to participate in the LSC. As the system was developed to be used with video data, the LSC data was transcoded into 114 videos with a frame rate of 5 fps. These videos can be explored using feature maps as shown in Figure 2, which map all of the frames to a map according to different aspects. Retrieval is handled via concept and metadata search, sketch search, and similarity search.

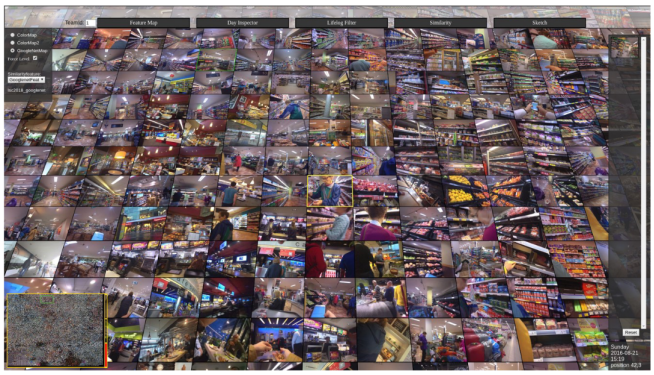

Figure 2. One of lifeXplore's feature maps

These are some examples to highlight the differences between the lifelog search systems. There are many other lifelog search systems and, so far, each edition of the LSC has resulted in the development of more search systems. This is a promising trend for the research fields of lifelogging and retrieval and for the lifeloggers who will hopefully get to use these systems.

3. RESEARCH QUESTIONS AND GOALS

3.1. Research questions

The main theme of this research project is lifelogging, which creates huge amounts of data. In this study, we focus particularly on the image data type. Lifeloggers create huge sets of images by regularly capturing images using small, body-worn cameras. There are many possible motivations why people practice lifelogging and many possible things they can do with such a huge number of images. Previous research on this subject identified a number of possible uses, but these were not suggested by actual lifeloggers. Conducting research using actual lifeloggers is useful to confirm the findings of previous work and to enhance the existing findings with new insights gained from the lifeloggers. Gaining more knowledge regarding the motivations and data usage of lifeloggers will improve future interface and interaction design in the field of lifelogging. This knowledge gap will be filled by studying actual lifeloggers instead of random participants. Moreover, the previous research in this context was conducted at least six years ago, which is a long time when it comes to fields with quickly evolving technologies such as the field of lifelogging. The questions this study aims to answer related to these knowledge gaps are as follows:

- *Lifelog motivation*
  Research question 1 - What are the major motivations behind lifelogging and creating lifelog image archives?
- *Data usage*
  Research question 2A - What are the most common usages of such lifelog image archives?
  Research question 2B - What are potential other uses that people may have for lifelog image archives and why are they not using them for this purpose right now?

Research questions 1, 2A, and 2B are part of the study to identify the motivations and behaviour of the lifeloggers and to provide a knowledge base regarding the lifeloggers. This basic understanding will be key to identifying and understanding the search motivations of lifeloggers and how they conduct their searches. Do lifeloggers search for a specific image or for information found in multiple images? How do they conduct their searches exactly? Being familiar with the motivation and behaviour of lifeloggers allows us to achieve the main goal of this study.

The main goal of this study is to find a way to realistically simulate search tasks and to figure out how to test them. Given the huge amount of data produced while lifelogging, it is not surprising that current lifelog research is mostly focused on the search problem. This results in a need for realistic, simulated search tasks to test lifelog image searching systems. However, it is hard to simulate these realistically since it is unknown how lifeloggers search through their data, as lifelog data is different from other kinds of data. Identifying the search motivations and search strategies of lifeloggers will allow researchers to better simulate search tasks as they will have a better idea of the thoughts behind the searches. The research questions related to searching are as follows:

- *Search strategies*
  Research question 3 - What searches are conducted by lifeloggers to find information in lifelog image archives?
- *Search tasks*
  Research question 4 - How can search tasks be simulated and tested?

Research question 4 is central to the main goal of this study and the answers and findings of research questions 1, 2A, 2B, and 3 will be key to answering this question.

3.2. Contributions

Our research makes the following contributions to the fields of lifelogging and information retrieval:

- The motivations behind lifelogging are discovered. This allows for a better understanding of lifeloggers, which is beneficial for future lifelog research.
- The details of lifelog image usage are discovered. This knowledge can be used to help future researchers and developers when working on lifelog image software or hardware and is also useful in the domain of information retrieval.
- The searches conducted by lifeloggers and the motivations behind these searches are discovered. It is important to identify how lifeloggers conduct their searches to create new or improve existing search software in the future. Initiatives like the Lifelog Search Challenge (LSC) use simulated search tasks

and would benefit from a better understanding of simulated search tasks. Better simulated search tasks would result in better lifelog search systems developed by the participants.
- Other improvements to the search tasks or the procedure of academic events are identified, which could used to improve these events and the evaluation of lifelog search systems.

4. METHODOLOGY

This study investigates lifelogging by means of three materials: online surveys, semi-structured interviews, and a review of academic events. Section 4.1 describes the different materials used. Section 4.2 looks at the different groups of participants and finally Section 4.3 describes the coding strategy and the analysis methods that were used.

4.1. Materials

4.1.1. Online surveys. Three online surveys were deployed in this study to collect data. The surveys were created and hosted using Qualtrics [17] with a license provided by Utrecht University and were presented in English. A consent form was presented at the start of each survey and participants had to agree with this form to proceed to the survey. If they did not agree the survey was ended immediately.

The surveys were filled in by three target audiences: lifeloggers, GoPro users, and lifelogging researchers and event organisers. The advantages of online surveys are their global reach and the ease of obtaining a large sample [18]. The target audiences in this study are spread thin across the globe, which made the use of any other data collection method nearly impossible. Besides that, other methods of data collection do not have the same ability as online surveys in terms of gathering a large number of responses. Reaching the target audiences and collecting a significant number of responses were key to answering the research questions.

4.1.2. Survey distribution. The three surveys were distributed in different ways. The surveys for lifeloggers and GoPro users were published on a number of online communities. These communities are used by lifeloggers and GoPro users to connect with others who share their interests. These communities were found by searching the internet.

The following communities were used for the lifelogger survey:

- Narrative Clip Lounge (Facebook) [19]
- The Quantified Self (Facebook) [20]
- Lifelogging subreddit (Reddit) [21]
- Quantified Self subreddit (Reddit) [22]
- Wearables subbreddit (Reddit) [23]
- The Quantified Self (separate forum) [24]

And the following communities were used for the GoPro user survey:

- GoPro subreddit (Reddit) [25]
- GoProDIY subreddit (Reddit) [26]
- ActionCams subreddit (Reddit) [27]
- GoPro HERO 9 (Facebook) [28]
- GoPro MAX and Fusion 360 camera users and fans (Facebook) [29]

4.1.3. Survey questions for lifeloggers. The online survey for lifeloggers was divided into sections as follows: It started with the collection of demographic information from the participants. The demographic questions collected data regarding the gender, age, and country of residence. Following this, questions regarding the lifelogging habits of the participants were asked. This included questions about how much they lifelog, why they started doing it, where they store their data, and if they ever delete some of the data. After that a set of questions covered the lifelog usage of the participants. This section included questions on how lifeloggers use their data, what they like or dislike about using their lifelog, and if they ever search for images or information in their lifelog. A mix of open and closed questions were used in this survey. A bias could potentially be introduced in the closed questions by suggesting certain answers. This was avoided as much as possible by ensuring that participants view all answers as equal and valid and by providing an opportunity for participants to add answers they think were missing via text entry.

4.1.4. Survey questions for GoPro users. The online survey for GoPro users was divided into the same sections of *habits* and *data usage* as the lifelogger survey. However, the demographic questions were not included in this survey in an attempt to increase response rate. In the habits section, the participants were asked questions about what data they capture, where they store it and if they delete any data. In the data usage section, the participants were asked about how often they look at their data, what other things they do with the data, and if they ever search through their data. This survey also used a mix of open and closed questions similar to the lifelogger survey. However, an effort was made to decrease the time needed to complete the survey, again to increase the response rate as much as possible. This meant that closed questions were used more and that open questions were all made optional.

4.1.5. Survey questions for lifelogging researchers and event organisers. The third and final online survey was sent to lifelogging researchers and organisers of academic events such as the LSC and focused on the tasks that are used in such events. This survey also did not include any demographic questions as this data was deemed to be less important than it was in the case of the lifelogger survey. Instead, the importance lied on the research experience of the participants in the field of lifelogging. In this survey, the participants were asked about what they consider the biggest research challenges in relation to lifelogging, how to improve the current tasks and events, and what other tasks could be included in future events. On the final page

of the survey the researchers were asked if they are active lifeloggers themselves. If so, they were asked to also fill out the survey for lifeloggers. Finally, they were also asked to participate in semi-structured interviews.

4.1.6. Semi-structured interviews. The lifelogging researchers and event organisers were also invited to participate in semi-structured interviews. These interviews were held with the goal of going more in depth into the subject of the tasks used in academic events such as the LSC. The semi-structured nature of the interviews helped to explore any unexpected insights that could not be provided via the online surveys. A script was prepared beforehand and was followed during the interviews while leaving room to deviate from the script to explore unexpected insights. However, a return to the script was always made to ensure all questions were covered and no bias was introduced. The interviews were conducted virtually using Microsoft Teams or Zoom [30] [31].

4.1.7. Consent form. A consent form was included at the start of each online survey and was also provided before every semi-structured interview. Without consent the participants could not fill in the survey or participate in an interview. Participants had to consent to the use of their (anonymised) data and responses in this study. Moreover, participants that were interviewed had to consent to the recording of the interview. The interviews were recorded for the purpose of transcribing the questions and responses.

4.1.8. Review of academic events. Finally, a review of academic events was conducted to gain a better understanding of the different tasks and events that are currently out there and to identify any trends. The Lifelog Search Challenge (LSC) [4], ImageCLEF [32], NTCIR [33], MediaEval [34], TRECVID [35], and the Video Browser Showdown (VBS) [36] were selected for this review. These events were either selected for having tasks related to lifelogging or for having tasks similar to the known-item search task currently used in the LSC. A comparison was made between the events and between different years in which these events were held. This resulted in the identification of a number of trends which are covered in Section 5.5.

4.2. Participants

As mentioned before, three groups of participants were used to collect the necessary data; lifeloggers, GoPro users, and lifelogging researchers and event organisers. This section covers these participants.

4.2.1. The lifeloggers. The lifeloggers were recruited via convenience sampling, although not just anyone was asked to participate. The online survey was published on several different online lifelog communities. This approach was chosen to ensure enough participants were found and that only lifeloggers would respond. Recruiting them through other means was not viable as lifelogging is a niche field with not many active participants. Therefore, the internet was used as it provides the widest reach, recruiting as many lifeloggers as possible.

The following demographic data was gathered from the lifeloggers via the online survey:

- Number of participants: 31
- Gender distribution: 14 male, 5 female, 1 other, 11 no answer
- Age distribution:
  - 18-24: 9.7%
  - 25-34: 19.4%
  - 35-44: 16.1%
  - 45-54: 12.9%
  - 55-64: 3.2%
  - 65-74: 3.2%
  - no answer: 35.5%

4.2.2. GoPro users. GoPro users were included in this study to supplement the data collected from the lifeloggers. GoPro users wear cameras in a similar manner to lifelogging and collect data that is similar in some ways to lifelog images. Therefore, learning how these users behave and what they want can help to understand lifeloggers as well. Similar to the lifeloggers, the GoPro users were recruited via convenience sampling. The previously covered online communities were used to publish the online survey. A total of 134 responses were gathered from this group, resulting in a much higher number of responses than in the case of the lifeloggers. No demographic data can be reported as the the demographic questions were not included in this survey.

4.2.3. Lifelogging researchers and event organisers. The lifelogging researchers and event organisers were recruited via purposive sampling, as they were selected for their research experience in the field of lifelogging to provide insights that could not be obtained from regular lifeloggers. A list of potential participants was made by finding all participants and organisers of the past LSC competitions and also adding some organisers from other events such as NTCIR, ImageCLEF, and LTA2016. This resulted in a list of 107 potential participants, of which 8 could not be reached due to deactivated email addresses resulting in a final tally of 99 potential participants. No demographic data was collected as explained previously. A total of 38 responses were gathered from the researchers and organisers.

4.3. Coding and analysis methods

4.3.1. Coding. Before any analysis could be conducted, the collected survey responses and interview answers had to be coded. According to Gibbs [37]; "Coding is a way of indexing or categorizing the text in order to establish a framework of thematic ideas about it". Every interesting bit of text was assigned a certain code, which resulted in the pieces of text being grouped together according to their content or theme. An open or emergent coding strategy was used in this study. This means that the list of codes used

was created along the way and was not set beforehand. This was an appropriate strategy as it fit a study with an inductive approach.

4.3.2. Content and thematic analysis. The analysis methods used in this study are content and thematic analysis. These methods are closely related and often used to analyse qualitative data. Content analysis is defined as a systematic, replicable technique for compressing many words of text into fewer content categories based on explicit rules of coding [38]. Thematic analysis is a method for identifying, analysing and interpreting patterns of meaning (themes) within qualitative data [39]. Both of these methods were employed to discover the underlying themes and identify the bigger picture from the collected qualitative data.

5. RESULTS

5.1. Lifelogger survey results

As covered previously, there were a total of 31 responses to the lifelogger survey. Unfortunately, out of these 31 responses, only 13 contributed useful data. This amount of data was insufficient to code. However, some interesting insights were gathered from this data, although more research should be conducted in the future to confirm these insights.

- **Motivation:** The biggest motivator behind lifelogging that was identified from the lifelogger survey is "fun". Participants considered capturing the images or browsing through them to be fun.
- **Deleting images:** Deleting images is not that common among lifeloggers, but when they do delete something it is often because the image is bad quality, mostly black, a duplicate, or a floor shot.
- **Biggest frustration:** The most common frustration among participants is the difficulty of searching through their many captured lifelog images.

5.2. GoPro survey results

Because of the disappointing response rate of the lifelogger survey the GoPro survey was added to this study. As mentioned, GoPro users wear cameras in a similar manner as lifeloggers, suggesting that they are faced with similar issues in relation to their data. A closer look at these users may therefore provide some insights into lifelog-related aspects as well. The GoPro survey had a much higher response rate with a total of 134 responses. The survey questions resulted in a number of interesting observations about the GoPro community.

As seen in Figure 3, GoPro users overwhelmingly store their captured data in self-organised folders (67.4%), with a minority using cloud storage (21.5%) or storage applications (7.6%) instead.

Figure 4 shows that the vast majority of GoPro users delete data either frequently or occasionally (46.6% and 42.1%), while only a small minority (11.3%) keeps all of their captured data. This means that GoPro users have to access their data often and in a labor-intensive manner if they want to keep filtering or cleaning their captured data. This is also supported by the next figure.

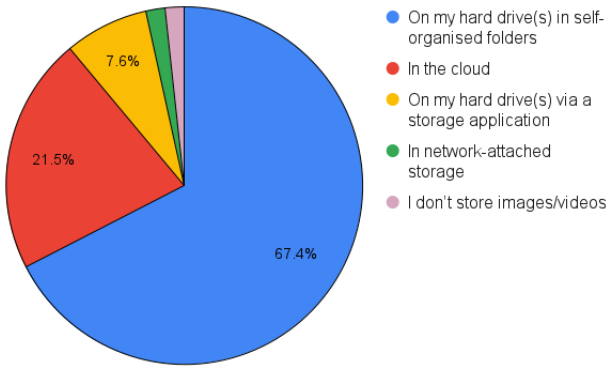

Figure 3. Where do you store your GoPro images or videos?

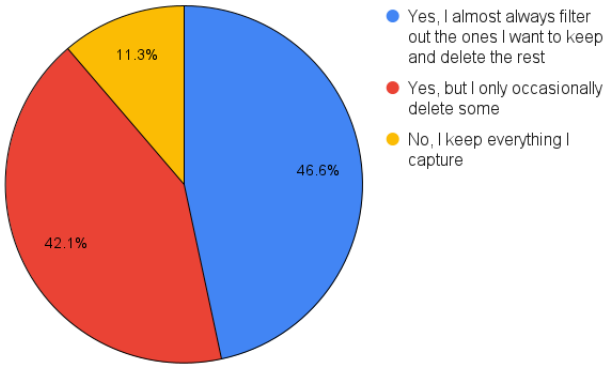

Figure 4. Do you ever delete any captured images or videos?

Figure 5 highlights that almost all GoPro users (95.1%) browse through their data. This is a huge number and highlights the need for specialised applications that support

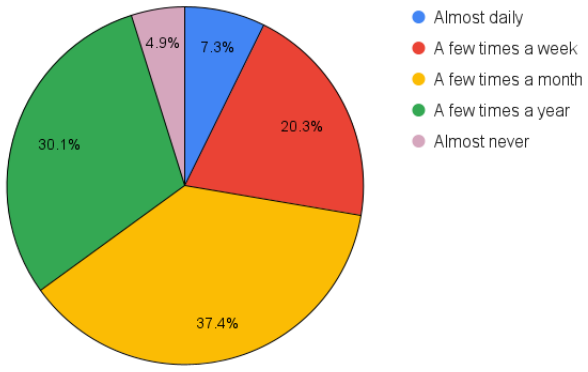

Figure 5. How often do you look at some of your captured images or videos?

searching and browsing through this kind of data.

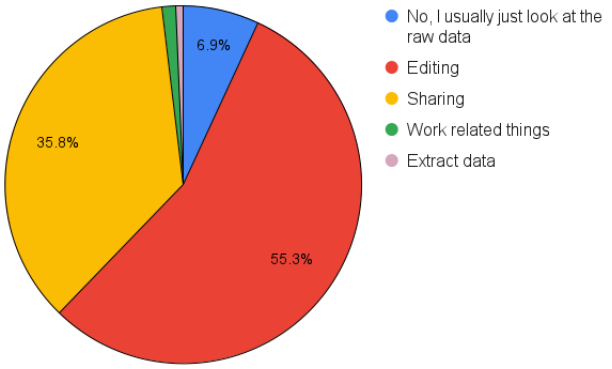

Figure 6. Do you do anything else with your captured images or videos?

As seen in Figure 6, the most common things GoPro users do with their data are editing and sharing (55.3% and 35.8%). The majority of GoPro users capture videos or time-lapse videos (79.92% combined), so it makes sense that editing is the most common thing GoPro users do with their data. The raw video footage is first edited so that it can then be shared with friends and family, social media, or on YouTube.

Figure 7 shows a division within the GoPro community. Almost half of the users access their data directly (46.8%), while the other half either uses GoPro software (26.2%) or other software (27%). The most popular examples of such software used by GoPro users are the Adobe suite (including applications such as Photoshop, Premiere Pro, and After Effects) and DaVinci Resolve. An interesting insight to add is that a number of participants mentioned that they did not like the standard GoPro software or found it hard to work with. This ties in with the need for new or improved specialised applications to use with GoPro (or lifelog) data. Apparently, the current GoPro software may not be fully up to the standards and needs of the GoPro users.

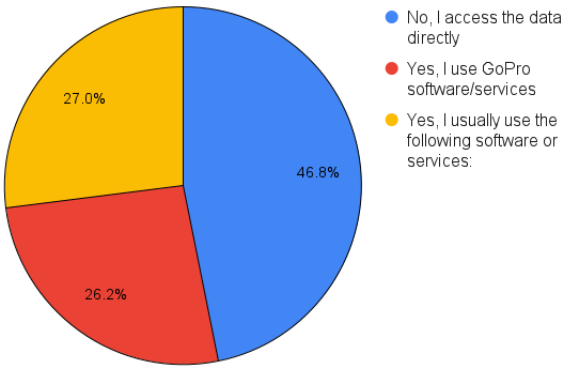

Figure 7. Do you use any application or tool to access and browse your captured images or videos?

Figure 8 shows that a lot of GoPro users (70.8% combined) frequently or occasionally search for images, stills

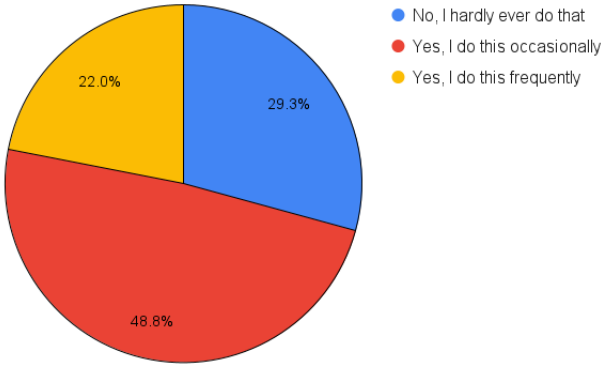

Figure 8. Do you ever search for particular images or information in your videos?

or particular information within their captured videos. This once again highlights the need for specialised applications to support browsing and searching within GoPro or lifelog data.

Two important open questions of the GoPro survey are covered below. An open question results in qualitative responses that are all slightly different from each other, and as such the responses to these two questions were coded. The used codes are also covered here. The first open question was:

> Can you explain what you find **most exciting/enjoyable** when going through or searching in your captured images or videos?

This question resulted in 57 different responses. These responses were coded and divided into the following categories:

Codes	Responses
Reminiscence	26
Finding a great image or shot	12
Discovering something you missed in the moment	9
Sharing	7
Learning to become better at using a GoPro	2
Good video quality	2
Quick system response	1
Editing	1

TABLE 1. THE MOST EXCITING OR ENJOYABLE THINGS WHEN GOING THROUGH CAPTURED IMAGES OR VIDEOS

As Table 1 shows, reminiscence is by far the most common answer to this question. Apparently, GoPro users love to browse their data to relive their highlights. This is in line with the previous research covered in Section 2. Both the work of Chen et al. and that of Caprani et al. [8] [9] include reminiscing or keeping things for sentimental value as reasons to capture (lifelog) data.

The second open question was:

> Can you explain what you find **most annoying/frustrating** when going through or searching in your captured images or videos?

This question resulted in 56 different responses from GoPro users which have been coded and divided into the following categories:

Codes	Responses
Too much data	13
Software doesn't do what I want it to do	11
Data is not what I wanted (low quality, bad angle)	8
Processing the data is hard or cumbersome	8
Going through the data takes too long	4
Hardware doesn't do what I want it to do	4
Too much useless or redundant data	4
Naming the data is tedious	4

TABLE 2. THE MOST FRUSTRATING OR ANNOYING THINGS WHEN GOING THROUGH CAPTURED IMAGES OR VIDEOS

Table 2 shows that there is a multitude of annoyances and frustrations for GoPro users. The overarching theme here seems to be the issue of dealing with a huge amount of data. This issue is covered by codes such as *too much data*, *processing the data is hard or cumbersome*, *going through the data takes too long*, and *too much useless or redundant data*. Combining these issues with the problem of *software doesn't do what I want it to do* highlights the fact that a lot of GoPro users are struggling to handle the amount of data they have with the current generation of applications or tools.

5.3. Lifelogging researchers and event organisers survey results

The survey for lifelogging researchers and event organisers had a total of 38 responses and after removing the responses that were not filled in completely 23 responses remained. With 99 potential participants this results in a response rate of 23.23%. This section covers the results and insights gained from four open questions and two closed questions.

Codes	Responses
Query building	4
Feature extraction/detection	4
Similarity of images	3
Accuracy	3
Multi-modality of data	3
Supporting the search	2
Gap between images and semantics	2
Unstructured data	1
Data storage	1
Efficiency	1
Amount of data	1
Access to more data sets for evaluation	1

TABLE 3. MAJOR SEARCH-RELATED RESEARCH CHALLENGES IN RELATION TO LIFELOG DATA

When asked about the major search-related research challenges in relation to lifelog data the participants gave a wide variety of answers as seen in Table 3. The wide variety indicates that there is not really one major challenge that everyone can agree on. However, there are some themes to be found here. One major challenge is found in relation to the data, which is signified by codes such as *similarity of images*, *multi-modality of data*, *unstructured data*, and *amount of data*. It seems that lifelog data is unique in terms of multi-modality and similarity, which makes it difficult to build search systems for. This ties in with the highest ranked challenges of *query building* and *feature extraction/detection*. Building a query that accurately returns what you are looking for from a huge amount of multi-modal, highly similar, and sometimes unstructured data is difficult. Moreover, the success rate of these queries is highly reliant on the ability of the search system to detect features in the data. All in all, there are quite some hurdles that must be jumped before a search system can accurately and efficiently return results.

Codes	Responses
Privacy	6
Data acquisition	6
Data quality/cleaning	6
Search system UI	3
Security	2
Data storage	2
Browsing/exploration	2
Lifelog summarisation	1
Lifelog analysis	1

TABLE 4. MAJOR NON-SEARCH-RELATED RESEARCH CHALLENGES IN RELATION TO LIFELOG DATA

Asking the researchers and organisers about major non-search-related research challenges resulted in an equally wide variety of responses, as seen in Table 4. In this case the researchers and organisers seem to be mostly split between three major challenges; *privacy*, *data acquisition*, and *data quality/cleaning*. Privacy is a challenge in terms of the GDPR in combination with the constant capturing of images or videos [40]. A large amount of these images or videos will contain the faces of people who have not given their explicit consent to be photographed or filmed. This is a non-issue when the lifelog data is for personal use only, but a huge issue when the lifelog data is meant to be used by researchers to evaluate their search systems. Before the lifelog data can be used in such a way it has to be made GDPR compliant, which is done by blurring or otherwise anonymising any faces and other personal information of people who have not explicitly consented.

This ties in with the challenge of *data quality/cleaning*. Cleaning the data set and making it GDPR compliant is a very labour-intensive process. This process can not be left in the hands of computer vision applications as these are not faultless. Leaving even one face unblurred could spell disaster as non-compliance to the GDPR is met with fines of up to millions of euros. Therefore, the process must be carried out in a (mostly) manual manner by researchers or others hired to complete this difficult task.

The third non-search-related challenge tied for first among the researchers and organisers is *data acquisition*. The LSC and other events currently use a single data set containing data from a few, non-consecutive months captured by a single lifelogger. While the participants state that they are happy with the availability of this data set, they

also indicate that they would like to get their hands on a lot more data to improve the evaluation of their search systems. Acquiring this data is difficult however as there are not many lifeloggers who would share their whole life for the purpose of search system evaluation. Moreover, the data would have to be cleaned and made GDPR compliant before it could be used, which is very labour-intensive.

The results of the first closed question of this survey can be found in Figure 9. Participants were asked to specify the most relevant tasks for lifelog data and could give multiple answers. As seen in Figure 9, the *Known-Item Search task* was deemed the most relevant. This is not surprising as this is a key task in the evaluation of search systems and is therefore featured in many events such as the LSC, ImageCLEF, NTCIR, and VBS.

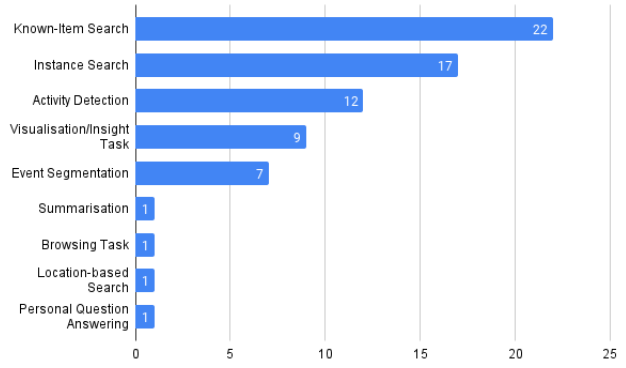

Figure 9. What do you consider the most relevant search tasks for lifelog data?

The task that finished in second place is the *Instance Search task*. In this task participants are not asked to find a single image or scene as in a KIS task, but instead have to find multiple instances of a person, object, activity, etc. This task is currently used in the TRECVID and VBS events and is deemed highly relevant by the participants. Adding this task to more events could be beneficial to further improve the search systems and their evaluation at the same time.

Finally, the other tasks that received more than one vote are not directly related to retrieval, but to features of search systems that support retrieval and browsing. In an *Activity Detection task* participants have to ensure their search system can automatically detect what activities are present in an image or a scene. Automatically detecting these activities allows the lifelogger to search for an image using the detected activities. A *Visualisation/Insight task* involves the automatic creation of information visualisations or insights from the provided lifelog data. This could be another useful addition to a lifelog search system as it creates something useful for the lifelogger from the huge amount of lifelog data. The *Event Segmentation task* is all about automatically detecting and segmenting different events in the lifelog data. The segmented events can then be shown to the lifelogger to allow for easier browsing or searching.

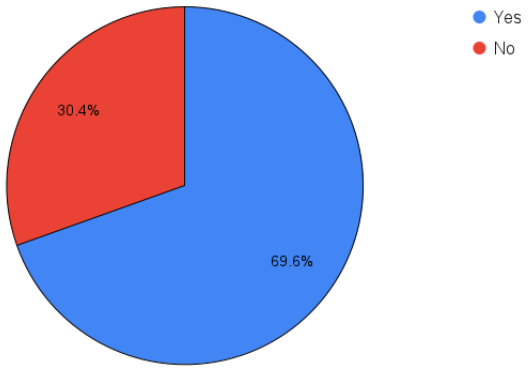

Figure 10. Do you think this is the best way to simulate a KIS task for lifelog data?

The second closed question of the researcher and event organiser survey was about the current procedure of KIS tasks during the LSC. Currently, the LSC simulates KIS tasks by showing textual descriptions of an event or image that participants need to find. These descriptions are split into small chunks of text that are shown step-by-step, meaning the description becomes more detailed and accurate as time passes. Figure 10 shows that 69.6% consider the current procedure of the KIS task to be the best, while the other 30.4% think it could be improved in one way or another.

Figure 11 shows the answers to an open question asking the participants what they would propose to improve the procedure of the KIS tasks. Four out of five proposals change the way the information about the target image or scene is provided to the participants. Three separate proposals want to change the way the textual description is handled. They would either give the participants the full description at the start of a query, reveal more information after a wrong submission rather than after a set amount of time, or have fewer steps that provide more information. The fourth proposal would add visual hints to the description to create a "multi-modal query".

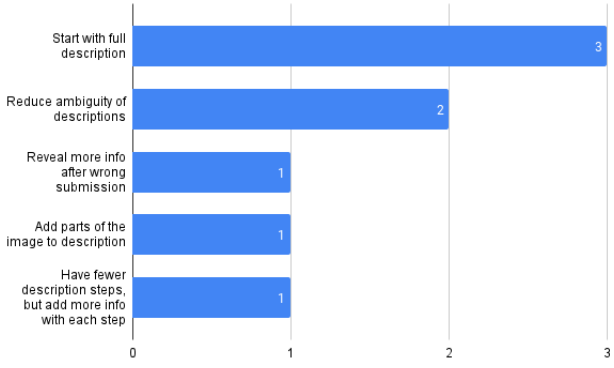

Figure 11. How could the simulation of a KIS task for lifelog data be improved?

Small parts of the target image could be added for

example. The fifth and final proposal wants to reduce the ambiguity of the textual descriptions. While this proposal only has two votes, this issue was raised by more participants in other survey responses and was also discussed in the interviews. The problem is that a submission is seemingly correct when looking at an early textual description, but in reality is incorrect. This is only revealed when more information is added to the description. This is why many participants consider it highly risky to submit their answer to a query at an early stage and would rather wait for some more information to confirm the accuracy of their answer.

The final question of the survey for researchers and event organisers was an open question asking them to think of anything else that could be done to improve the evaluation process of these events. The wide variety of answers can be found in Figure 12.

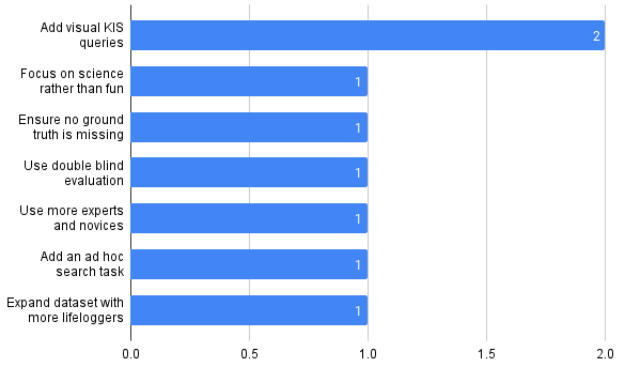

Figure 12. Do you have any other comments on how the evaluation procedure at the LSC or related events could be improved?

The improvements in Figure 12 will be covered in the next section in combination with the interview results as they cover the same theme.

5.4. Interview results

The researchers and event organisers were recruited for the interviews via the online survey they participated in and via email as well. Six semi-structured interviews were conducted with four organisers and two participants. These interviews have resulted in a huge amount of useful insights on the different facets of academic events such as the LSC. Five of the six interviews were recorded and transcribed, while notes were taken during the sixth interview. The responses were coded and grouped according to their content and theme. This section will cover the questions and responses. The interview began with some questions about the participants involvement in the LSC and about any potential lifelogging experience. The responses to these questions are not covered below as they did not contribute any useful data or insights.

5.4.1. The data set. The first questions of the interview that did contribute useful insights cover the data set used in the LSC and other related events. Participants were asked about their views on the data set and could answer in any direction they wanted. Examples of such directions were the size and the representativeness of the data set. The responses were divided into two groups: the current state of the data set and the future state of the data set.

The current state of the data set is covered first. Two things all could participants agree on were the high quality of the data set, but also it's small size. However, the participants also agreed that getting more data into the data set is very difficult, as it needs to be anonymised to comply with the GDPR. One upside of the current small size is that it welcomes new systems that might not be able to handle larger data sets yet. In terms of representativeness, the data set could be improved. Currently, the data set contains many images of offices, laptops, and computers, etc. According to the participants this means the search systems are very good at recognising these things, but not so good at recognising other things that are not so common in the data set. Adding the data of other lifeloggers, especially of those not working in an office, would improve the representativeness and would also train the search systems to recognise other contexts better. An additional point is the fact that the data set is currently very image focused. It does contain other data such as biometrics, but these are not very precise yet.

The future state of the data set covers changes or additions that could be made to improve the data set. The first and most important improvement according to the participants is the addition of more data to the data set. This could be more data from the current lifelogger or data from lifeloggers that are currently not part of the data set. The latter would also help with the representativeness. Another change would be to focus not so much on image data, but to improve the quality of the other data to make the data set more multi-modal.

5.4.2. The novices and experts. One core facet of the LSC is the use of two groups of people for the evaluation of the lifelog search systems: novices and experts. The experts are the people who have developed the search system and therefore know (almost) everything about it, while the novices are randomly selected people from the conference audience who know nothing about the system they are about to use. Both of these groups have to find answers to a certain number of queries. The interview responses related to novices and experts were also divided into two groups: the current state of novices and experts, and the future state of novices and experts.

The current state is covered first. Five out of six participants were highly positive about the use of these two groups, while the sixth participant questioned the use of novices. The upside of having a novice group is the added element of usability. The developers can not just focus entirely on the performance of their system, but must also make it usable and understandable for novices. However, there are also downsides to the use of novices. They are randomly selected from the audience and thus a random element is added to the competition. It is possible to end up with a novice who

knows much about multimedia retrieval and is therefore able to perform very well, while it is also possible to end up with a novice who has never even heard of retrieval and might perform awfully (even with a user-friendly system). Moreover, the participants mention that it is sometimes hard to find novices during a conference and that the pool of potential novices is small.

The participants had a number of suggestions in relation to the future state of novices and experts. The first and foremost suggestion is to increase the number of novices used in these events. The variability of using novices will decrease when using more novices according to the participants. Besides this, a method has to be found to decrease the variability even more. One suggested method is to rotate the novices between systems after a few tasks. However, as one participant mentions, the novices also have a learning curve and generally need to complete a few queries to become comfortable with the system. Rotating them too soon does not let them reach this level of comfort with the system and will negatively affect their performance. Another proposed method of decreasing variability is to let two novices use one system and selecting the better performing novice.

Finally, some other changes were proposed by the participants. First, an extension of the duration of the event would allow more expert and novice tasks to be completed. This would decrease the variability and make the results more generalisable. Second, the recruiting process for novices could be improved. Currently, the experts need to find a novice in a matter of minutes. One participant proposes a volunteering system to gather interested novices beforehand to ensure the availability of enough competent novices. Third, adding the lifelogger(s) themselves as a third group for evaluation purposes was proposed by one participant. Since they are they are already very familiar with the data this would allow for the comparison of systems from the point of view of the lifelogger.

5.4.3. The queries. The queries and the procedure of the queries were the next topics of discussion during the interviews. The queries of the LSC are currently conducted as follows: A textual description is shown to the participants. This description is expanded with additional information about the target image(s) every 30 seconds. Participants are awarded points based on the time it takes them to submit the correct answer and the number of wrong submissions they made before submitting the correct answer. Once again the responses of the interview participants were divided into two groups: the current state of the queries and the future state of the queries.

The current state of the queries is covered first. Half of the participants do not consider the number of queries to be very important, while the other half would like to have more queries during the competition. However, it is important that the fatigue of the participants and the audience is taken into account when determining the number of queries. The participants agree that the procedure of the queries is currently quite good, but that it could be improved. One of the problems that five out of six interview participants mentioned is the ambiguity of early textual descriptions. An LSC participant might think they have found the correct image for a certain query as it corresponds to the textual description at that moment. However, the submission actually turns out to be incorrect, although this is only revealed after more information is added to the description. This is an annoying issue according to the participants as it makes submitting early quite risky. Finally, the participants mentioned that the queries are currently very good in terms of using the images of the data set, but do not really use other data such as biometrics. Adding queries that do use these kind of data will ensure that the search systems are more robust and can handle diverse queries.

The participants also had a few suggestions for the future state of the queries. As mentioned previously, half of the participants would like more queries, although the fatigue of both the participants and the audience must be taken into account. Additionally, the participants want to fix the problem of ambiguous text descriptions and have different suggestions for this fix. Instead of giving more information over time, the information could be added as a result of wrong submissions. In this case, wrong submissions would not be penalised, although the system with the lowest number of wrong submissions would probably win. A different way of fixing the ambiguous descriptions is to ensure that there is something unique or deterministic in the first description and to add the less important information in later steps. This way, the participants will know they found the correct image when they find the unique or deterministic element. Finally, the interview participants want to see more diverse queries, which could be achieved in different ways. Queries that use data other than images could be used or queries that use visual descriptions instead of textual descriptions can be added to the competition. The reason behind the wish for diverse queries is to make the search systems more robust and versatile.

5.4.4. Other tasks. The interview participants were also asked if they wanted to see any tasks other than the current known-item search task. Three of the six participants were in agreement and mentioned an *instance search task* that is also used in other competitions. This task is similar to the current task, but requires participants to find multiple instances of a query instead of just one. According to them, such a task would fit the current procedure and theme of the competition without taking away from the fun of it. Two other participants proposed to add a summarisation task to the event, although they admit this would be harder to evaluate than the current task.

5.4.5. Other research challenges. During the final question of the interview the participants were asked what non-search related research challenges they would like to see covered by the LSC or by related events. The participants came up with question answering, automatic things such as lifelog summarisation, exploration, and privacy.

5.5. Review of academic events

The final material of this study is a review of academic events. For this review the LSC, ImageCLEF, NTCIR, MediaEval, TRECVID, and the VBS were reviewed. The focus of this review lied on the tasks used in the different events and in the different years of the events. The aim of the review was to identify task-related trends. Four of these task-related trends were identified.

5.5.1. Known-Item Search Tasks. The first trend is the inclusion of known-item search tasks in all of the events covered in this review. Moreover, all events use textual queries for their KIS tasks, although the VBS uses both textual and visual queries. The use of textual queries in all events could indicate that event organisers consider a textual query to be more realistic. It is currently unknown why the visual queries are not used more. As covered previously, some of the survey and interview participants mentioned that the addition of visual queries would be useful.

5.5.2. Instance Search and Ad-hoc Video Search Tasks. The second trend is the use of instance search and ad-hoc video search tasks by the VBS and TRECVID. These two tasks are highly similar and can be applied to different data such as images and videos. For these tasks both textual and visual queries are used. As with the previous trend, survey and interview participants were interested in the addition of an instance search task to the LSC. Moreover, it is interesting that retrieval tasks remain the most common task at such academic events.

5.5.3. Visualisations and Insights. The third trend is related to visualisation and insight tasks. These tasks are not related to retrieval, but instead focus on creating visualisations and extracting insights from lifelog data. These tasks are part of multiple events such as NTCIR and MediaEval and do not really focus on the competitive element. Instead the participants present their work after it is completed. Some of the participants of the researcher and organiser survey also chose visualisation and insight tasks as potentially valuable tasks for future events. While unrelated to retrieval, these tasks could help develop features that support retrieval in other ways.

5.5.4. Activity Detection. The fourth and final trend is the common use of tasks related to detecting activities, settings, or events. Such tasks are present in TRECVID, NTCIR, and ImageCLEF and while they are not the same they do share a similar goal; automatically detecting activities, settings, or events when provided with a data set. This is also a type of task not directly related to retrieval, but more related to supporting retrieval or exploration. Searching or browsing becomes much easier when the user can use a list of tags to search or when browsing process is sped up by the availability of automatically detected and segmented events.

6. DISCUSSION

The aim of this study was to find answers to questions related to the motivation behind lifelogging, the use of lifelog data, the search behaviour of lifeloggers, and the simulation and testing of search tasks. Following the coverage of the methodology and the results, the answers to these research questions are discussed in this section.

6.1. Research question 1

As covered in the related work section, one of the existing knowledge gaps within the field of lifelogging relates to the lifeloggers themselves. One of the aims of this study was to fill that knowledge gap by studying the lifeloggers directly. The goal of the first research question was to discover the major motivations behind lifelogging and creating lifelog image archives. However, answering this question has been made difficult due to the disappointing response rate to the lifelogger survey. To supplement the data from the lifeloggers the GoPro users were added to the study. While this has resulted in an influx of useful data, the nature of the results showed that there are more differences between these groups than one would assume. Therefore we cannot answer research question 1 and future work must be conducted to confirm or disprove the following anecdotal statements that can be made based on the limited amount of data that was gathered.

The big takeaway from the lifelogger survey is that most lifeloggers simply consider fun to be their biggest motivation. If this turns out to be true, more research should be conducted in the future to discover what the lifeloggers consider to be fun. Yet, this observation differs from the existing literature on this subject, which presents other motivations such as reminiscence, memory support and sharing.

If true, such a difference would also confirm that there is indeed a need to research actual lifeloggers instead of non-lifeloggers, as the two groups have different motivations. This is further supported by the fact that GoPro users do consider reminiscence to be a a major motivation, which means that lifeloggers and GoPro users differ from each other in terms of motivation. However, it should be kept in mind that the data set was rather small and may have been biased.

To summarise, it is not possible to give a conclusive answer to this question as there is just not enough lifelogger data available. Therefore, the inconclusive answer to research question 1 is that fun may be the major motivation behind lifelogging. Additionally, the difference between the lifeloggers, the participants of previous research, and the GoPro users confirms that there is a good reason to research lifeloggers themselves rather than non-lifeloggers.

6.2. Research question 2A

The goal of the second research question was to identify the common usages for lifelog image archives. Again, the low response rate does not allow for any conclusive answers.

However, the lifelogger survey did identify some usages for lifelog image archives. The responses mentioned things such as reminiscence, medical reasons, discovering information, and fun. The GoPro survey identified editing and sharing as the most common usages. The difference between the lifeloggers and GoPro users seems to be that GoPro users collect their data to share with others, while lifeloggers collect the data for themselves. However, the GoPro users did mention reminiscence as their favorite thing about going through their data, meaning the lifeloggers and GoPro do have something in common. Reminiscence was also found to be an important motivation in existing literature. Therefore, the inconclusive answer to research question 2A is that reminiscence is the most common usage for lifelog images archives and one of the most common usages of GoPro data.

6.3. Research question 2B

Research question 2B sought to identify other potential usages for lifelog image archives and also aimed to identify why these other usages were not currently in use. The lifelogger survey identified that the biggest frustration among lifeloggers is a lack of searchability of the data. This was also an issue among GoPro users, who had a number of complaints concerning the amount of data and the fact that it is hard to browse or search through such an amount of data. All in all, there is a need for robust software that can handle the amount of data produced by lifeloggers and GoPro users. When such software is released, the lifeloggers and GoPro users can finally search and browse with ease. Therefore, the answer to research question 2B is that searching and browsing are two important potential usages among lifeloggers and GoPro users. These activities are currently hard to do because of a lack of software up to the task. This need for robust searching software signifies the importance of events such as the LSC.

6.4. Research question 3

The aim of research question 3 was to identify the search behaviour of the lifeloggers and GoPro users. The answer to research question 2B already highlighted the importance of searching and browsing as it is something that many lifeloggers and GoPro users would like to do. However, before this study it was unknown exactly how they search or what they search for. The lifelogger survey revealed that two-thirds of the participants search for both images and information, although this should be taken with a grain of salt due to the low response rate. A majority of GoPro users are also used to searching with 70.8% occasionally or frequently searching for particular images or information. These results confirm that searching is important both for lifeloggers and for GoPro users. Additionally, these results indicate that the participants are equally likely to search for a particular image as they are to search for information within the data.

This is key information for lifelog search system developers, as it is clear they need to support both types of information needs. This result is also important for the simulation of search tasks, as there is confirmation that lifeloggers are equally likely to search for images as they are to search for information. With this confirmation, the organisers of the LSC and related events can create search tasks that simulate both of these information needs.

6.5. Research question 4

The aim of the final research question was to discover how to simulate search tasks or how to improve the current simulation. The researchers and organisers provided a huge number of insights in this regard. There are a lot of different elements in play when simulating and testing these search tasks, so these elements and the insights for each element are covered separately below.

The first element is the data set used during the search tasks. To improve the simulation and the evaluation of the search systems there should be a few improvements made to the data set according to the participants. More data should be added to make the simulation more realistic. Additionally, data from more than one lifelogger should be used in the data set. While this is difficult to achieve in terms of GDPR compliance, the participants indicate that this would be a valuable addition to the data set, which would improve the simulation and the evaluations. Another improvement that could be made is to make better use of the multimodality of the data set. The current search tasks are based predominantly on the images of the data set, while there are a lot of other data types present that could be taken advantage of.

The second element is the novices and experts used during the competition. While the participants agree that both novices and experts should continue to be a part of the competition, almost all participants want to shift the focus more towards the novices. Moreover, the participants agree that there is too much randomness involved with the recruitment and performance of novices. Two ways of decreasing the randomness were proposed by the participants: Either rotate the novices between the search systems after a few tasks or have multiple novices per system and select the best performing novice for each system. Currently, the skill of the novices varies too much and these proposals would decrease the variability that influences the evaluation.

The third element is the queries that have to be answered during the competition. While most participants agree that the current queries are good, they do propose some improvements to make them even better. The biggest issue with the current queries is the ambiguity of some of the descriptions. This ambiguity discourages the participants to submit an answer that they think is correct at an early stage as it is too risky. Instead, they wait until they have more information to confirm the correctness of their answer. According to the participants this issue could be resolved in different ways. On one hand, adding a unique or deterministic element to the initial description could make the description less ambiguous and reduce the risk of submitting early. On the other hand, more information could be added to the description as

a result of wrong submissions rather than with the passing of time. In that case, the wrong submissions would not be penalised directly, although the system with the least wrong submissions would more than likely win. Something else the participants could be done is to expand beyond the current textual descriptions. One proposal is to add visual hints for some of the queries, which could be achieved in different ways. Parts of the target image, a blurred image, or scrambled image could be used. This would help mimic the (bad) memory of the lifelogger according to the participants.

Finally, many of the participants mentioned the value of adding the instance search task to the competition. As confirmed by research question 3, the lifeloggers and GoPro users are not always looking for one specific image, but also for information which could be found in more than one image. The latter scenario would be easier to simulate with an instance search task rather than a known-item search task.

6.6. Limitations

As already stated above, the most important limitation of this study was the disappointing number of responses to the lifelogger survey. This low response rate required the addition of the GoPro users to this study. Even though these participants provided useful data, the initial goal of researching the lifeloggers themselves could not be achieved. While it is unfortunate that these observations could not contribute to answering our research questions as much as we hoped, it does illustrate the relevance of our research, as it shows that lifelog data is different from GoPro data. Even though we could not conclusively answer research question 1, we still obtained insights that are relevant for future work.

7. CONCLUSION AND FUTURE WORK

The main motivation behind this study was to discover more about lifeloggers to fill the current knowledge gaps related to this group of people. Additionally, academic events and their tasks were studied and reviewed with the aim of identifying potential improvements. With these improvements the search systems can be evaluated in a more optimal manner, which will ultimately benefit the lifeloggers. The combination of these two research goals also reveals if state-of-the-art research is moving in the right direction to benefit the lifelogging community.

Although not conclusively proven, our study has found anecdotal evidence that lifeloggers consider fun to be their biggest motivation, while GoPro users consider reminiscence as their main reason behind collecting data. This difference highlights the need to focus more research on the lifeloggers themselves, which should be taken into consideration in terms of future work. The fact that most lifeloggers consider fun to be their biggest motivation should act as a reminder that any current or future lifelog search systems should be user-friendly and easy to learn. This will boost the attractiveness of lifelogging and could result in an influx of new users.

In terms of data usage, the results indicate that reminiscence is important to the lifeloggers while GoPro users consider editing and sharing to be the most important data usages. Moreover, both the lifeloggers and GoPro users wish it was easier to search or browse through their data. The combination of these two insights indicates that there is a strong need for robust search systems with the capabilities to handle huge amounts of data. This indication justifies the focus laid on retrieval by the academic events as these events help develop state-of-the-art lifelog search systems.

When it comes to the search behaviour of the participants the most important insight obtained is the fact that both lifeloggers and GoPro users search for both images and information in their data. This is especially important for the development of the lifelog search systems and should be researched further in future work. Gaining an even better understanding of the search behaviour benefits the simulation of search tasks as well.

Finally, a large number of potential improvements for the simulation of search tasks were identified. The data set should be expanded with more data and more lifeloggers to improve the evaluation of the search systems, although this will not be easy as the data set needs to remain GDPR compliant. Additionally, the multi-modality of the data set should be taken advantage of more. In terms of the participants of the academic events, the focus should be shifted more towards novices. More novices should be recruited and an effort should be made to decrease the impact of the variability caused by a difference in the skill of the novices. This could be done by rotating the novices between systems or by letting multiple novices use one system and selecting the best performing novice. When it comes to the queries there is also a number of improvements proposed by the participants. The textual descriptions should be made less ambiguous with the addition of a unique or deterministic piece of information to the initial description. A different method would be to reveal more information after a wrong submission rather than with the passing of time. This would remove the risk of submitting early as you can not just wait for more information. Something that should also be considered is the addition of visual information to the descriptions. This would make the queries multimodal and would simulate the vague memories of the lifeloggers. This visual information could be included in the form of blurred or scrambled images, or by showing small cutouts of the target images. A final improvement could be made by adding an instance search task. Results from the lifeloggers and GoPro users show that they search for both specific images and information found in more than one image. The latter scenario can be simulated using this instance search task. This would improve the evaluation and make lifelog search systems more multifunctional.

The combination of the two research goals shows that the state-of-the-art research is moving in the right direction, although there is room for improvement. Lifeloggers have a clear need for robust search systems to support their search behaviour and researchers are currently developing and evaluating these systems. The methods used to evaluate

the search systems should be improved using the aforementioned insights. Moreover, it is key that the needs of the lifeloggers are taken into account during the development process, which emphasises the need for more research in relation to the lifeloggers.

To summarise, a number of improvements could be made that would improve the evaluations conducted during the LSC. Of course, these insights can also be applied to other existing events or used to start entirely new events. Future work must be conducted to closely compare different tasks or different types of queries, since this study only collected the opinions of researchers and organisers without supporting it with a quantitative evaluation of tasks or queries.

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PART II

Annotated Appendix

1 Motivation and Overview

Collecting personal data and keeping track of your habits, diet, and behaviour has never been easier than it currently is. The ubiquity of (relatively) cheap technology such as smartphones, wearable devices, and body cams are the major causes for this along with the availability of cheap data storage in the form of hard drives and cloud services. Many people make use of these technologies to capture and store data, although none are more passionate about it than the so-called lifeloggers. This group of people has taken personal data collection to the next level, as they are almost always capturing data in one way or another. The data captured includes images, video, audio, GPS coordinates, accelerometer data, heart rate, steps taken, calories consumed, etc. The amount and diversity of the data are the reasons why the term *Personal Big Data* was coined by Gurrin et al. to describe lifelog data [1]. This introduces one of the major problems within the lifelogging community: How can lifeloggers make use of such big data?

One solution to this problem is a lifelog search system. Such a system can best be compared to a search engine like Google or Bing, although a lifelog search system is developed specifically for lifelog data. The developers have to implement features that allow the user to search using the different modalities of the data. However, the fact that the lifelog search systems have to handle such a huge amount of highly personal, multimodal data makes the development and evaluation of these search systems difficult. This is the main reason why the Lifelog Search Challenge (LSC) was started. The LSC invites researchers to develop lifelog search systems to compete in an interactive search challenge, which serves as an evaluation method for these search systems. The fourth edition of the LSC will be held in 2021 and the event has grown in popularity with each subsequent edition. The first edition featured seven systems, while the coming edition will feature sixteen different systems. While the LSC and other related academic events have proven to be useful (and fun), there is no current research that investigates these events and the tasks used during the events. It is possible that the procedure of the events and tasks could be improved to enhance the evaluations and in turn improve the lifelog search systems.

Another current knowledge gap relates to the users in this context: the lifeloggers. While there have been studies that researched the phenomenon of lifelogging by using non-lifeloggers as participants, there have been no attempts to do the same with actual lifeloggers. This has kept several knowledge gaps related to lifeloggers unfilled since the very beginning of lifelog research. Filling these knowledge gaps is not only important to support the development of lifelog search systems, but also to support other future work in the lifelogging field.

The most important knowledge gaps that currently exist relate to the motivations, data usage, and behaviour of lifeloggers. It is currently unknown why

they practice lifelogging, collect personal data or capture lifelog images. It is also unknown what they do with their data once it is captured, how and where they store it, and what their search behaviour looks like. Uncovering this information about the lifeloggers will benefit the developers of lifelog search systems, as they will be able to better focus their efforts on features important to the users.

Combining these two research directions and filling these knowledge gaps benefits the lifeloggers, the researchers involved in the field of lifelogging, and the developers of the lifelog search systems. Moreover, it will indicate whether or not the state-of-the-art research is moving in the right direction.

A literature review was performed to support this study and to identify the state-of-the-art research and the existing knowledge gaps. This literature review is covered in Section 2. Following this, Section 3 covers a review of academic events. Relevant academic events, their tasks, and a number of identified trends were reviewed with the aim of investigating the current practices to identify any potential improvements. Finally, Section 4 covers the different materials that were used during this study and the data analysis that was applied to the collected data.

2 Literature Review

This section covers the literature studied in preparation of and during the thesis project. To support the thesis project, numerous different fields of research have been studied. First, the central theme of lifelogging is covered and explained in detail in Section 2.1. Numerous smaller elements of lifelogging such as lifelogging technologies and lifelogging cameras are also discussed. Section 2.2 then covers lifelog data usage. Finally, Section 2.3 covers some of the different lifelog search systems that exist and have participated in events such as the Lifelog Search Challenge.

2.1 Lifelogging

Lifelogging is defined by Dodge and Kitchin [2] as:

> a form of pervasive computing, consisting of a unified digital record of the totality of an individual's experiences, captured multi-modally through digital sensors and stored permanently as a personal multimedia archive.

Essentially, lifelogging produces a huge amount of data regarding the personal life of the lifelogger. As the definition mentions the data is captured multimodally, meaning that the data comes in many shapes and sizes. This data is divided into the following classes by Machajdik et al. [3]:

- *Passive Visual Capture:* A popular activity among lifeloggers is to wear cameras that capture images every so often, for example every 30 seconds. This method captures thousands of images every day, creating huge data sets.
- *Personal Biometrics:* Medical data captured on wearable devices like wristbands. This data includes number of steps taken, distance travelled, caloric output, sleep duration, and sleep quality.
- *Mobile Device Context:* Data can be captured from the mobile devices of lifeloggers. This method of data collection can be carried out both passive and active. This data includes the device location, speed and movement. Smartphones can also record other environmental data such as pressure, temperature and humidity.
- *Communication Activities:* Communication Activities: This data covers digital communication such as phone or video calls, emails, text messages, and social media activity.
- *Data Creation/Access Activities:* Other activities than communicating with others can also be recorded on computers, laptops, tablets, and smartphones. This refers to the data created and accessed when working with these devices.

- *Active Capture of Life's Activities:* This class of lifelog data refers to things such as blogs or status updates on social media. This data is not always captured passively and is not "always on" which is why it is debatable whether this is actually lifelogging.

There are many reasons lifeloggers decide to record their lives. The so-called quantified self is an important reason. *Quantified self* is a term coined by Wired magazine editors Gary Wolf and Kevin Kelly [4]. According to them the quantified self is

> a collaboration of users and tool makers who share an interest in self knowledge through self-tracking.

This interest in self-tracking is what drives many lifeloggers to record more and more data. One goal of the quantified self and self-tracking is to improve health and wellness. Currently, the focus of many lifelogging applications and tools is on improving health and wellness, as stated by Gurrin et al. [1]. To achieve this goal the lifelogger must be able to access the data and understand it. This is a returning challenge in the lifelogging field. Portraying the data in an understandable and attractive way allows the lifelogger to understand it better and lets them take action accordingly.

2.1.1 Lifelogging technologies

Lifelogging is not necessarily a new field of research, but has been around for some time. The initial birth of lifelogging dates back to 1945 when Bush proposed the Memex [5]:

> The Memex is a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory.

Obviously, this Memex does not look at all like modern lifelogging technology that can passively record data for its user. However, the proposal of the Memex signifies the need and the desire to record and quantify the activities, thoughts, communications, and other aspects of one's life. After the Memex proposal it took years for the lifelogging field to gain traction and attract more researchers and developers. With the invention of computers, the internet and bodycams the field has become increasingly popular and a lot of research is being conducted. The widespread use of smartphones, smart watches, and fitness trackers has allowed everyone to become a lifelogger with ease and since storing large amounts of data has become much cheaper it does not require much effort or money to start lifelogging.

There has also been development of devices specifically for the purpose of lifelogging. A number of bodycams have been developed and introduced to consumers and those have been used heavily by lifeloggers. Examples of these devices are the OMG Life Autographer, Narrative Clip, iON SnapCam, and

YoCam [6] [7] [8] [9]. These devices allow the lifeloggers to easily capture thousands of images without much effort as these cameras are small and usually clip easily onto clothing or are wearable with a lanyard around the neck.

2.1.2 Wearing a lifelogging camera

Wearing a camera on your body and capturing images of everything around you is an interesting idea, but does not come without issues. It is quite obvious that walking around with a camera will result in privacy issues with the random people captured in the images. This is an issue that many lifeloggers struggle with and was also the focus of a study conducted by Koelle et al. [10]. Their study covers the result of an online survey conducted among lifeloggers regarding the use of a lifelogging camera. They found that the majority of lifeloggers do not try to hide their lifelogging camera when they are wearing it, although they also tend to not point it out themselves. Additionally, a lot of lifeloggers tend to self-censor their images to be more ethically correct and not hurt the privacy of others.

2.1.3 Discussion and conclusion

The section above was meant as an introduction to the field of lifelogging. Lifelogging is not yet as widespread or mainstream as other technological trends which is why an introduction is helpful to fully understand the context of this study. The aim of the section was to provide basic background knowledge to help support other, more in-depth sections that dive deeper into lifelogging. In conclusion, there are many ways to practice lifelogging and many different kinds of data to be captured as covered by Dodge and Kitchin [2]. One of the goals of this study is to discover why exactly people like to capture all of this data.

2.2 Lifelog data usage

The central element of lifelogging is capturing personal data and lifelog images. However, it is not entirely clear what uses the lifeloggers have for their collected data and images. Some research has been conducted in this direction however. The first of these papers is by Caprani et al. [11] and tries to uncover the motivation behind the collection and keeping of life-long memory collections. The researchers conducted interviews with ten younger and ten older participants. The participants were not lifeloggers, but were asked questions regarding themselves and their motivations and practices. The interviews resulted in the identification of five major motivations:

- *Memory support:* This motivation was found to be key among the participants. This makes sense as reviewing taken pictures can make people remember events of the past that they had previously forgotten. Reviewing a photo album of a vacation trip will elicit many more memories than simply thinking about the vacation trip or talking about it.

- *Sharing:* Another reason for the participants to collect images and data is to share it with others. This happens in different ways. Some participants mentioned inheriting memories from their deceased relatives and friends. Taking care of belongings that were once important to a now-deceased loved one is a large responsibility signifying the importance of the relationship with the deceased. A different way of sharing is through social media. This is done in a more casual way as the sharing is done with a larger group of people with varying levels of closeness to the sharing person.

- *Precaution:* The third motivation to keep memories, pictures and other documents is "just in case". Some of the items kept by the participants did not necessarily have a purpose at that time, but the participants felt the need to keep them as they might have a purpose in the future. This was mostly applicable to medical, legal, and financial documents. However, some receipts associated with happy memories were kept for their sentimental value.

- *Sentiment:* The fourth motivation, as mentioned in the previous subsubsection, is sentimental. Items kept for this reason were mostly given or sent to them by loved ones, attaching a special sentimental value to them. Attachments to these items or pictures strengthened over time.

- *Family background:* The final mentioned motivation was the family background of certain memories and pictures. This motivation ties into other motivations such as sentiment and memory support. One theme mentioned by many participants was creating and keeping a family tree. This family tree would have as many family members as possible with pictures and other memories to accompany them.

Caprani et al. also find that the motivations are not set in stone and change during the course of one's life. One important pattern found was that the older participants were generally more dedicated to collecting memories and pictures and were also more attached to these memories.

Another paper written on this subject is by Chen and Jones [12]. This paper also researches the motivation behind lifelogging. The research was conducted with 414 participants who were not necessarily lifeloggers, but were recruited through a paid-survey service. The participants were first introduced to lifelogging and asked about their opinions and wishes regarding lifelogging. The majority of the participants would wear a wearable camera and let it continuously take pictures during the day. In terms of applications for the lifelog data, the participants named a number of different suggestions:

- *Reminiscing:* The participants suggested "reminiscing" as the main usage for lifelog images. Participants want to relive the past or review interesting holidays and events.

- *Memory backup:* Using lifelog images as reminders for important events and facts. Reviewing these images would improve the memory of the participants.
- *Telling and passing life stories:* Passing on memories to loved ones is an important usage for lifelog images according to the participants. This goes for lifelog images, but also for memories in other shapes such as autobiographical works.
- *Re-use:* This usage for lifelog data is similar to memory backup. The lifelog data would be saved in some way so it could be used in the future.
- *Evidences:* A more niche reason to collect and keep lifelog images and other data is to use them as evidence in court may the need arise.
- *Collection and archiving:* Collecting objects or other things is a hobby of many people and the same goes for the participants in this study. Many suggested the fun of collecting as a motivation to capture lifelog images and other data.
- *Learning about unknown early age:* This motivation revolves around collecting memories from the early age of the children of participants. It might be hard to have children wear lifelog cameras (and it might be an ethical issue as well). However, the participants could wear the camera themselves and through that capture images and other data regarding their children's life to review when they grow up.
- *Well-being and better organization:* Using lifelog images and other data to improve one's well-being is the final important motivation for lifelog data collection. Collecting and reviewing images and data allows the participants to review their life in a sense and notice any bad habits or patterns that they would like to change.

2.2.1 Discussion and conclusion

The usage of lifelog data has been studied in two separate papers, but so far never with actual lifeloggers. Despite this, the studies conducted with random participants still provided interesting results. There is a significant overlap between the found uses for lifelog images and other data. Examples of this overlap include boosting memory (memory support / memory backup), re-telling stories (sharing / telling and passing life stories), keeping things for potential later use (precaution / re-use), saving things for their sentimental value (sentiment / collection and archiving), and keeping memories of the family (family / background). These motivations could result from a study featuring lifeloggers, although it is possible that there are other motivations that have not been identified by only researching random participants. This is a big knowledge gap and an opportunity to gain new insights.

2.3 Lifelog search systems

To enable lifeloggers to search and browse through their lifelog data, particularly lifelog images, lifelog search systems are being researched and developed. These search systems are then evaluated in academic events such as the Lifelog Search Challenge (LSC). During the LSC the search systems are used to find the answers to simulated search tasks. As the field of lifelogging has become a more and more active field of research, the number of different lifelog search systems in development has also gone up. The most recent edition of the LSC featured fourteen lifelog search systems from 11 countries and the next edition, LSC'21, features sixteen lifelog search systems. This section covers some of the different lifelog search systems that have been developed for the LSC in the past years.

2.3.1 Virtual Reality Lifelog Explorer

The winner of the first edition of the LSC, LSC'18, was the Virtual Reality Lifelog Explorer developed by Duane et al. [13]. As the name suggests, this is a search system that makes use of a virtual reality interface. The user wears a VR headset to browse and search through the lifelog images and other data. The reasoning behind the use of VR is the expectation of Duane et al. that VR will become widespread in the near future. The Virtual Reality Lifelog Explorer lets users create queries using two sub-menus: the tags sub-menu and the temporal sub-menu. The tags sub-menu is used to select a number of tags corresponding to objects, people, activities, settings, or contexts that are found in the lifelog images. The temporal sub-menu is used to select the temporal aspect of the query such as the date and time. Combining these two sub-menus results in queries such as: "using the computer on a Saturday afternoon". After a query is created, the user is shown the results in a decreasing ranked order. The highest ranked result will be the one that matches the most selected queries and the selected time and date. The research of Duane et al. has found no significant benefits for the use of VR in combination with a lifelog search system, but found no significant drawbacks either. Figures 1 and 2 show the two sub-menus of the Virtual Reality Lifelog Explorer.

Figure 1: The tags sub-menu of the Virtual Reality Lifelog Explorer

Figure 2: The temporal sub-menu of the Virtual Reality Lifelog Explorer

2.3.2 vitrivr

The winner of the second edition of the LSC, LSC'19, was the vitrivr system developed by Rossetto et al. [14]. This is a content-based multimedia retrieval stack initially built for the Video Browser Showdown, which is another retrieval competition focused on videos. While the LSC does not have any videos in their data set, the vitrivr system could be applied to the LSC without much difficulty as both events feature a known-item search task. The vitrivr system can be used in different ways to search for images. Three of these ways are Query-by-Sketch (QbS), Query-by-Example (QbE), and Relevance Feedback. The QbS and QbE interfaces can be seen in Figures 3 and 4. QbS allows the user to draw something from their memory and the system will find images that resemble the drawing, while QbE allows the user to set one image as an example and the system will find images that share some resemblance to that example. Finally, the Relevance Feedback method allows the user to mark images as relevant or non-relevant and the system will focus on finding similar images to the ones marked as relevant.

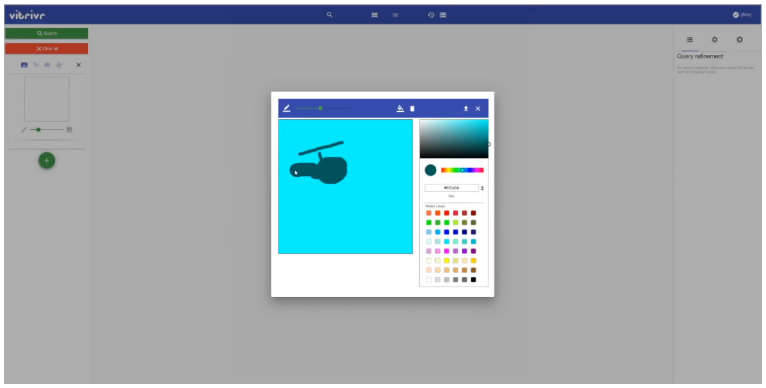

Figure 3: Query-by-Sketch interface

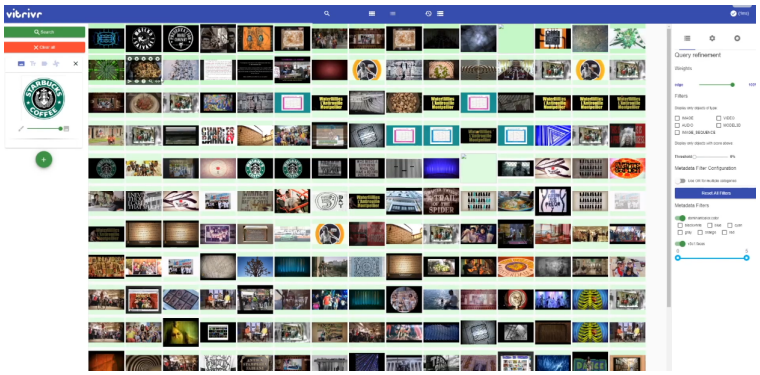

Figure 4: Query-by-Example interface

2.3.3 lifeXplore

One of the participating systems of the third edition of the LSC, LSC'20, was the lifeXplore system [15]. This is also a system that was originally developed for the Video Browser Showdown. It was called diveXplore at that time, which stands for *distributed interactive video exploration* [16]. Before this system could be used in the LSC, the lifelog data set was first transcoded to a video format. This ensured that the system recognized the data and could search through it. One of the main features of the lifeXplore system are the feature maps. This can be seen in Figure 5 along with the rest of the architecture. The feature maps sort the images according to extracted features, allowing the user to search, browse, or highlight similar images. Other methods of searching included in the system are concept and metadata search, sketch search, and similarity search.

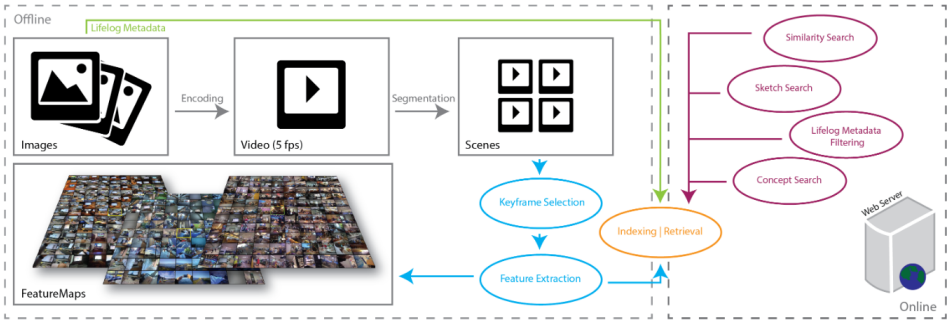

Figure 5: The architecture of the lifeXplore system

2.3.4 LifeSeeker

One of the systems that will participate in the fourth edition of the LSC, LSC'21, is the LifeSeeker system by Le et al. [17]. This system has also participated in LSC'19 and LSC'20 and was originally developed for an NTCIR event. The LifeSeeker system was developed specifically with novice users in mind and a user study was performed to enhance the usability of the system. The user has two ways of searching with LifeSeeker: by inputting a textual query in a Google-style search bar or by using a filtering system that allows for detailed filtering. The LifeSeeker system makes use of additional concept detection, which automatically tags images with the concepts it finds. This is an important process as it enhances the power of the textual query input by the user.

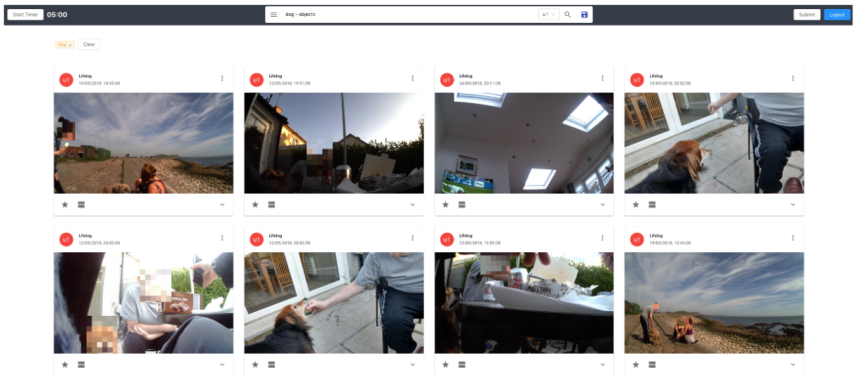

Figure 6: The LifeSeeker system showing the results of a textual query

2.3.5 LifeGraph

A system that employs a different strategy when it comes to retrieval is LifeGraph by Rossetto et al. [18]. This system is focused on capturing the internal relations between the various modalities of the data. This is done using knowledge graphs. Each knowledge graph defines three things: two resources and one relation that connects them. The second focus of the system lies on linking the lifelog data to large static knowledge bases. This link is meant to enrich the semantic context of the lifelog data. Retrieval using the LifeGraph is conducted by the specification of a query by the user. The user selects any number of tags that relate to the target image. Once the query is formulated the system traverses the graph looking for relevant images. After these relevant images have been found the user can apply filtering to further specify their information need.

2.3.6 Discussion and conclusion

The lifelog search systems covered above are just a small part of the whole group of systems. Some systems use similar methods of retrieval, while others make use of entirely different methods. It is also interesting to note the difference in interfaces (standard UI vs. virtual reality) and the difference in focus (more focus on the technical side vs. more focus on the usability side). Finally, the diversity of the systems highlights that there is currently not one definite way of developing a lifelog search system. This confirms the importance of academic events such as the LSC, which evaluate the search systems and encourage the researchers to keep improving them.

3 Academic event review

A number of academic events such as the Lifelog Search Challenge, ImageCLEF, NTCIR, etc. are covered in this section. The tasks featured in the events are covered and trends between these events are identified. This review was conducted to gain a better understanding of the different tasks featured in these events.

3.1 Event summary

There are a number of academic events similar to the Lifelog Search Challenge (LSC). These events, just like the LSC, revolve around one or more tasks that require participants to use a provided data set to complete a given objective. For example, the LSC provides participants with extensive lifelog data with which they train and test their search systems. These search systems then compete with each other in a competition to find out which search system is the most effective. Similar events with lifelog tasks include ImageCLEF, NTCIR, MediaEval, TRECVID, etc. This section will summarise these events in regard to the tasks they use.

3.1.1 Lifelog Search Challenge

The Lifelog Search Challenge (LSC) is an event held annually as part of the ACM International Conference on Multimedia Retrieval (ACM ICMR) and a focal point in this thesis project due to being based around the evaluation of lifelog search systems. The LSC currently consists of only a single task: The interactive search challenge. The goal of this task is to answer queries by finding the corresponding images in the lifelog. It can therefore be considered a known-item search (KIS) task. An example of such a query is "A red car beside a white house". The query starts with just a tiny bit of information, but every 30 seconds some additional information is given to the participants. At 150 seconds the example query looks like this "A red car beside a white house on a cloudy day. I had driven for over an hour to get here. It was a Saturday in August and it was in the early afternoon". The earlier a query is answered correctly the more points are awarded to the team that correctly answered it.

3.1.2 ImageCLEF

ImageCLEF is an event which has been organised annually since 2003 as part of the larger CLEF event and focuses primarily on automatic annotation and multimodal information retrieval. In 2017 the first iteration of ImageCLEFlifelog was held and this task continued to be part of the task lineup for the next four years, until 2021. The goal of ImageCLEFlifelog is to "bring the attention of lifelogging to an as wide as possible audience and to promote research into some of the key challenges of the coming years". ImageCLEFlifelog has two subtasks in each year that the event has been held:

The first subtask is Lifelog Moment Retrieval or Lifelog Retrieval (the task is the same, though the name changes slightly) which is used in all years between 2017 and 2020. LMRT is a task in which participants receive a query such as "Find the moment(s) when the lifelogger was having an icecream on the beach". The goal is to find lifelog images that match the query. The queries vary between KIS queries and queries in which there are many possible correct answers. The goal of the latter is to find as many correct answers as possible, while the goal of the former is to find a single correct answer (a correct answer could be found in multiple consecutive images of an event).

The second task of 2017 is Lifelog Summarisation (LST). In this task participants analyse all lifelog images and summarise them according to specific requirements. The summary will consist of 50 images that are both relevant and diverse. An example of this task is: "Summarise the use of public transport by a user". This would result in 50 images showing different means of public transport, potentially at different times to signify the diversity of the images.

The second task of 2018 is Activities of Daily Living Understanding (ADLT). In this task the participants analyse lifelog data and provide a summary based on certain concepts selected by the task organisers. These concepts include examples such as: commuting, travelling, preparing meals, in an office environment, in a home, etc. The summary includes the frequency and time spent for each concept and looks like this: "Eating/drinking: 6 times, 90 minutes", "Travelling: 1 time, 60 minutes".

The second task of 2019 is Solve my life puzzle (Puzzle). In this task participants are given a set of lifelog images with metadata, but without timestamps. The goal is to rearrange these images in correct chronological order and to predict the day (Monday or Sunday) and time of day (morning, afternoon, evening) when they were taken.

The second task of 2020 is Sport Performance Lifelog (SPLL). In this task participants are required to predict the performance (estimated finishing time, average heart rate, calorie consumption, etc.) of an athlete based on previous data collected from 16 people. This data includes sleeping patterns, heart rate, sport activities, image logs of all consumed food, etc.

These five ImageCLEFlifelog tasks revolve around concepts such as searching, summarisation, event segmentation, and prediction.

3.1.3 NTCIR

NTCIR is an event that has been held since 1999 and hosts a wide variety of tasks related to Information Access Research. The Lifelog task has been part of NTCIR since NTCIR-12 which was held in 2016. Just like ImageCLEFlifelog, NTCIR Lifelog also has one task that is present in every iteration and a number of tasks that are only present in some iterations. The tasks are explained below:

The Lifelog Semantic Access Task (LSAT) has been part of every NTCIR Lifelog since it was first held. In LSAT the participants have to retrieve specific moments in a lifelogger's life, these are called semantic events. This task is

also a known-item search (KIS) just like the LMRT task used in ImageCLEF. An example of an LSAT query is: "Find the moment(s) where I use my coffee machine". This task can be completed both interactively or automatically.

Another task used in multiple iterations of NTCIR is the Lifelog Insight Task (LIT). The goal of this task is to gain new insights into a lifelogger's life using lifelog data. A number of information needs are specified which have to be filled by the participants. An example of such an information need is: "Provide insights on the time I spend taking breakfast". There is not a real evaluation of the submissions, but instead all participants bring their insights and present them.

The Lifelog Event Segmentation Task (LEST) was part of NTCIR-13 in 2017. The aim of LEST is to examine different ways of event segmentation using continual lifelog stream data. The participants have to segment a set of lifelog data after which their segmentation is compared to a manual segmentation created by the lifeloggers themselves. The participants have to segment the data using a list of 15 activities such as travelling, cooking, social, creative, etc.

The Lifelog Annotation Task (LAT) was also part of NTCIR-13. The goal of this task is to use computer vision algorithms to describe the activities and settings found in the lifelog data. This task also has a set of concepts to choose from just like LEST does, meaning the two tasks are highly similar.

The Lifelog Activity Detection Task (LADT) is the final lifelog task used in NTCIR. It featured in NTCIR-14 in 2019. The goal of this task is to develop new approaches to the annotation of multimodal lifelog data. The focus of this annotation lies on another list of 16 activities that the participants must use, making the task very similar to the LEST and LAT tasks.

3.1.4 MediaEval

The MediaEval event has been held since 2010 and is focused on evaluating new algorithms for multimedia access and retrieval. The participants come from fields such as speech recognition, multimedia content analysis, music and audio analysis, user-contributed information, etc. MediaEval has a very broad genre of tasks, but only one is directly related to lifelogging. This is the Lifelogging for Wellbeing task:

In the Lifelogging for Wellbeing task the participants receive weather and air pollution data, lifelog images, and tags which have all been recorded by people who wear sensors. The participants then walk through a city along predefined routes and develop approaches that process the data to obtain insights about personal wellbeing. After this there are two subtasks to complete. The first of these is Segment Replacement in which participants build a system that can replace segments of data that have been removed. The second subtask is Personal Air Quality in which participants develop a system that can automatically predict personal AQI (Air Quality Index) at specific places or times using the data.

3.1.5 TRECVID

The TREC Video Retrieval Evaluation (TRECVID) event has been held as part of the larger Text REtrieval Conference (TREC) since 2003. The goal of the TRECVID conference is to encourage research in information retrieval. Over these years TRECVID has hosted over twenty different tasks related to information retrieval. However, to this day there have been no tasks directly related to lifelogging. A reason for this could be the fact that TRECVID is focused on video rather than on images, and video is currently not used as much for lifelogging purposes. However, one task that has been used in multiple TRECVID conferences, Instance Search, could be a valuable addition to the group of lifelog tasks. The Instance Search task revolves around finding as many "instances" as answers to a certain query. An example would be to find as many instances as possible of "Jack eating food". While TRECVID uses video as the data set for this task, images are similar enough to be used for a lifelog version of this task.

3.1.6 Video Browser Showdown

The Video Browser Showdown (VBS) is an international video content search competition held annually as part of the International Conference on MultiMedia Modeling since 2012. The VBS is very similar to the LSC in regard to the setup of the competition and the researchers organising the event. The VBS provides two different tasks as part of their competition: A Known-Item Search (KIS) task and an Ad-hoc Video Search (AVS) task. In the KIS task the participants get a visual or a text query and the goal is to find the item that matches this query. In the AVS task the participants get a broad text query with many correct answers. The goal is to find as many correct answers as possible.

3.2 Trends in events

This section will investigate any trends that can be identified by studying the different academic events covered above. Insights gained from studying these trends could be used to improve the academic events in the future.

3.2.1 Known-Item Search Tasks

The most common task among all academic events covered is the Known-Item Search (KIS) task. As explained above, the goal of the KIS task is to find the correct answer to a query. This query can be textual or visual. A textual query is a short text describing an image or a video clip, while a visual query is an image, a screenshot, or a short part of the video. The participants receive such a query and set out to find the correct answer using their search system.

The first trend that can be identified is as follows: all academic events that feature a KIS task use textual queries, although the VBS event uses both visual and textual queries. This could indicate that the academic events consider textual queries accurate simulations of a searcher's memories. It is unknown

why other academic events have not included visual queries in their tasks. The reason why VBS uses visual queries might be that the event is focused on video and the other academic events focus on images for their KIS tasks. Providing a visual query might make it too easy to provide the correct answer if the data set consists of images. Another difference between tasks is found in the textual queries. The VBS and LSC use textual queries that become more detailed over time. According to the VBS this simulates a person remembering more details over time and providing these details to the searcher. Other academic events like ImageCLEF and NTCIR do not change their textual query over time. The reason behind their decision is not provided.

To summarise, all events featuring the KIS task use textual queries while only one event uses visual queries. It is unknown why visual queries are not used more, though there are multiple possible reasons. First of all, it could make the queries too easy for the search systems as reverse image searching could be implemented. However, this can be prevented by changing the visual query image slightly. The image could be blurred, coloured differently, or parts of the image could be removed. Secondly, the only event that provides visual queries is the VBS which is an event based on videos rather than on images. The visual query simulates having a memory of a single frame of a video, which does not translate well to images. However, with some adapting the visual queries could be used to simulate a lifelogger's memory as well. Blurring the image or just showing some parts of the image would more realistically simulate human memory.

3.2.2 Instance Search and Ad-hoc Video Search Tasks

Two tasks that are highly similar and used in multiple academic events are the Instance Search (INS) task and the Ad-hoc Video Search (AVS) task. During these tasks participants are provided with textual or visual queries and asked to find as many correct answers to those queries as possible. This means that the queries are not focused on one answer like in the KIS task, but look at a much larger number of images. The AVS task is used in the VBS and TRECVID events and uses a textual query to provide the participants with a description of an image or event. This description is very general and does not get more detailed over time. The INS task is used in the TRECVID event and while the goal is essentially the same as the goal of the AVS task, the participants are provided with visual queries instead. These visual queries consist of four images of a specific person doing a specific action after which participants find as many examples of this combination as possible.

The trend identified previously also applies here with both events using textual queries and only TRECVID using a visual query for the INS task. However, the reasons are not exactly the same. The INS and AVS tasks are not focused on finding one specific event, therefore having one image as a query does not make sense. Instead, the queries are much broader and more general as participants are expected to find many answers to one query. In the case of these two tasks it makes more sense to provide textual queries, although the way TRECVID

utilises visual queries is also a possibility. Instead of giving the participants a single image, TRECVID provides them with multiple examples of a person doing an action. This makes it clear for the participants what they are searching for exactly.

3.2.3 Visualisations and Insights

A third identified trend is the inclusion of tasks focusing on creating visualisations or insights from a given data set. The NTCIR event hosts the Lifelog Insight Task while MediaEval hosts Lifelogging for Wellbeing. The goal for the participants is to interactively or automatically create visualisations or insights from the data given to them. There is no real competitive element included, instead the participants all present their work after it is completed. The visualisations should be interesting and provide new insights or ideas about the lifelogger and the data set. This trend follows the idea of the Quantified Self movement which focuses on visualising data from everyday life to gain self-knowledge. The Quantified Self movement has been closely associated with lifelogging so the inclusion of visualisation tasks is not surprising. Visualisations make lifelog data more useful to the lifelogger and therefore including this type of task would be valuable for an event focused on lifelogging.

3.2.4 Activity Detection

The final identified trend is the inclusion of tasks focusing on the detection of activities, settings, or events. These tasks are grouped together as they are highly similar and all have the same goal. TRECVID, NTCIR, and ImageCLEF all host multiple tasks that fit into this group. The goal of these tasks is to automatically go through a data set and detect or annotate the different activities, settings, or events. It is likely that this trend exists to accommodate the fact that huge data sets have become a lot more common due to the cost of data storage dropping and the ease of capturing data increasing. Working with data sets that have a large number of images or videos for example becomes increasingly difficult and cumbersome as the data set grows. Therefore it makes sense that there is increased interest in creating solutions to this problem such as automatic activity detection or annotation. Searching through such a large data set will become much easier if the data is automatically annotated, allowing the searchers to simply input a search term instead of going through images or videos.

4 Materials

The materials used in this study are covered in this section. First, the initial survey is covered in Section 4.1. Then the data collection as a whole is explained in Section 4.2 and finally the data analysis strategy is explained in Section 4.3.

4.1 Initial survey

An initial survey was performed to collect data from the first participant group, lifeloggers, and to investigate whether or not this research design was suitable for this study. This section covers the design and the results of this initial survey. The survey consisted of closed and open questions and was hosted on Qualtrics [19] using the license provided by Utrecht University.

4.1.1 Design

The initial survey of this study was published as an online survey. Previous research has shown that such a design can result in a significant response rate and valuable insights [10]. As covered in the literature review, Koelle et al. used an online survey to investigate lifeloggers in relation to wearing lifelog cameras. The researchers created an online survey and published it in a single online lifelog community, the Narrative Clip Lounge [20]. This community had around 2500 members (the exact number is not mentioned) at the time of the evaluation and 117 of these members participated in the study. This results in a response rate to the online survey of around 5%, meaning that the results are representative (if a non-systematic non-response bias is assumed). This level of response was promising for future work and was one of the reasons online surveys were used in this research project. However, since this project does not specifically study the use of lifelog cameras, other online communities were found and used to publish the initial survey in addition to the Narrative Clip Lounge. The reason behind this was to reach a group of lifeloggers that was as large as possible. Such a large population in combination with a high response rate would mean that the results of this study were generalisable to the entire population of lifeloggers.

The following online communities were used to publish the initial survey:

- Narrative Clip Lounge (Facebook) [20]
- The Quantified Self (Facebook) [21]
- Lifelogging subreddit (Reddit) [22]
- Quantified Self subreddit (Reddit) [23]
- Wearables subbreddit (Reddit) [24]
- The Quantified Self (separate forum) [25]

These communities were found by searching the internet for lifelog pages where lifeloggers can share their experiences and views. The survey was published on a Tuesday. Research indicated that Monday, Tuesday and Thursday are the best days to send out a survey, although this varies per survey and the means of publishing [26]. A reminder to participate was sent a week after the original data of publishing, again on a Tuesday at around the same time. After another week, the survey was closed and participants could no longer fill it in.

The initial survey was created from scratch as no existing surveys were suitable to be used in this study. Although other survey research had been conducted in the field of lifelogging, these surveys could not be used. The reason for this is the difference in focus and scope of the different studies. This study focused more on open questions to extract deeper insights from the participants. Existing surveys focused more on closed questions, and could therefore only be used as inspiration.

The questions of the survey were created by keeping the research questions of this study in mind at all times. Each question had to have a clear goal and questions that did not have a clear goal were scrapped to keep the survey as short and to the point as possible. Besides standard questions regarding consent and demographics, the lifeloggers were asked about their lifelogging habits and the usage of their lifelog. The following lifelog questions were included in the initial survey:

- What kind of lifelog camera do you use (or have you used)?
  - Narrative Clip
  - Narrative Clip 2
  - OMG Life Autographer
  - Vicon Revue
  - EE Capture Cam
  - YoCam
  - iON SnapCam
  - MeCam HD
  - Other:
- Which of the following statements best describes your lifelogging habits?
  - Permanent lifelogger: I log almost all of my daily life
  - Frequent lifelogger: I log frequently, but not every day
  - Occasional lifelogger: I log on certain days or occasions like holidays
  - Infrequent lifelogger: I log almost never
  - Ex-lifelogger: I used to lifelog, but don't do it anymore

  - Other, please explain:
- (Optional) Why did you start capturing lifelog images?
- Where do you store your lifelog images?
  - On a hard drive
  - In the cloud
  - In a storage application
  - I don't store images
  - Other:
- Do you ever delete any lifelog images?
  - Yes
  - No
- (Optional) Can you explain why you delete parts of your lifelog images?
- How often do you look at your captured lifelog images?
  - Daily
  - A few time a week
  - A few times a month
  - A few times a year
  - Never
  - Other:
- (Optional) Why do you look at your captured lifelog images?
- (Optional) Do you do anything else with the captured lifelog images?
- Do you use any application or tool to access and browse your captured lifelog images?
  - No
  - Yes, namely:
- Do you ever go through your captured lifelog images to find a specific image?
  - Yes
  - No
- Do you ever go through your captured lifelog data to find specific information?
  - Yes

– No

- (Optional) Can you explain what you find most exciting/enjoyable when browsing or searching in your captured lifelog images?
- (Optional) Can you explain what you find most annoying/frustrating when browsing or searching in your captured lifelog images?

4.1.2 Results

After two weeks of collecting data there were a total of 45 recorded responses. The data from these responses was first extracted from the Qualtrics website, after which it was reviewed. The distribution of participants can be found in Table 1. Responses are marked as spam by Qualtrics if there are multiple identical responses from the same IP address within a 12-hour period [27]. These spam responses were not included in the further reviewing of the data as they did not contribute in any meaningful manner.

Participant group	**Number of participants**
Total responses	45
Spam responses	14
Real responses	31

Table 1: Participant distribution

Table 2 shows which of the survey questions were answered by the participants. The majority of the responses were partial as finishing the survey was not mandatory. 18 out of the 31 real responses were ended either after the consent form or after the demographic questions, resulting in no meaningful data. That leaves a remainder of 13 participants who had filled in some or all lifelog questions.

Questions answered	**Number of participants**
Consent	8
Consent, demographics	10
Consent, some lifelog	3
Consent, demographics, some lifelog	4
Consent, demographics, all lifelog	6

Table 2: Questions answered by participants

There was no point in coding the responses because of the small number of meaningful responses. This unfortunately eliminated the possibility of qualitative or quantitative analysis. The only thing the responses could be used for was the extraction of interesting insights. Although the research questions can not be answered just with interesting insights, they could be useful for future research. The following insights were extracted from the responses:

- The majority of the participants lifelogs for fun or collects lifelog images because they are fun to browse.
- The most common reason to delete lifelog images is to get rid of images that are bad quality, mostly black, duplicates, or shots of the floor.
- Additionally, only a minority of participants delete parts of their lifelog images.
- The difficulty of searching through many lifelog images was the most common frustration of the participants.

4.1.3 Discussion

Unfortunately, the initial survey did not go as well as hoped as the response rate was much lower than expected. Despite the fact that previous research indicated that the use of online surveys was a valid research method in this context, the online survey did not deliver the number of responses required to perform a meaningful analysis. There is not one obvious reason why the online survey did not deliver in this case, but there are a number of possible reasons:

- **COVID-19 pandemic**
  The first possible reason for the disappointing response rate is the COVID-19 pandemic that was at it's height during this study. Capturing lifelog images is by definition something to do while you are out of the house. This is made difficult by the pandemic as going outside can be a health risk or forbidden by the government. Moreover, going on vacations abroad (and lifelogging during those vacations) is almost impossible due to many countries implementing travel restrictions. These hurdles and risks have taken away many of the incentives to practice lifelogging. This would explain why there was a lower interest in lifelogging during this study, resulting in the low response rate of the initial survey.
- **No lifelog cameras (currently) available**
  The second possible reason is the fact that few companies currently sell lifelog cameras. The most popular lifelog cameras, the Narrative Clip and the Narrative Clip 2, are currently out of stock and it is unknown if the company will ever produce more [7]. Other popular lifelog cameras such as the MeCam HD and the iON SnapCam are also no longer in stock [28] [8]. The seemingly only remaining option is the YoCam [9], which is still sold. Additionally, GoPro cameras could also be used for the purpose of lifelogging, although they are not optimised for this use. In conclusion, the difficulty of acquiring a lifelog camera does not make lifelogging any easier. This could demoralise newcomers to the field and turn away experienced lifeloggers seeking a replacement for their old equipment. The extra difficulty could explain why interest in lifelogging seems to be declining and why the initial survey had few responses.

- **Loss of interest in lifelogging**
  The third possible reason is a broader loss of interest in lifelogging. This was already implicated in the previous bullet, as there are few remaining lifelog cameras on the market. The need for a small wearable camera seems to have been eliminated. Perhaps the rise of smartphones and smartwatches have something to do with this. Most of the features found in lifelog cameras can also be found in smartphones, so it seems the continuous evolution of the smartphone (and the camera that is usually included) may have eliminated the need for a lifelog camera, as practically everyone now has a portable camera in their pocket. The broader loss of interest is evident from the lack of activity in online lifelog communities. Looking at archived posts and messages, the communities were more active a few years ago.

- **A potentially suboptimal survey**
  Finally, another possible reason for the low response rate is a suboptimal survey. As explained earlier, the initial survey was created from scratch as no existing surveys were suitable to be used. Although existing literature was consulted during the creation of the survey, it is possible that the survey was suboptimal. This could have resulted in a loss of interest from the participants, causing them to close the survey. The following section will describe some changes that were made to improve future surveys.

4.1.4 Improvements for future surveys

While the response rate to the initial survey was disappointing, online surveys are currently still the most viable method of reaching the target participants of this study. Therefore, online surveys were also used to reach the other target audiences. However, some changes were made to the surveys to increase the number of useful responses. These changes are covered in this section.

First of all, the subsequent surveys were made to be shorter. Despite an estimation from Qualtrics that it would take around seven minutes to complete the initial survey, it may have felt too long as the survey had multiple pages and a number of open questions. To make the survey feel shorter a limit of three pages was set. The first page is the consent form, the second page has all of the survey questions, and the third and final page thanks the participant and wraps up the survey. Liu et al. confirm that survey length has a negative influence on survey completion rate, so in theory a shorter survey should have a higher completion rate [29].

The second change made was the removal of the demographic questions in subsequent surveys. These questions were removed as there was a noticeable number of dropouts at the demographic questions. It is suspected that the demographic questions decrease the likelihood of a participant finishing the survey. This likely has something to do with privacy or anonymity concerns, as people are generally careful with sharing personal information on the internet. The target audience of the subsequent surveys were GoPro users, and researchers and

event organisers. The demographic data of the researchers and event organisers was much less relevant than their experience in the lifelog research field. Therefore, the removal of the demographic questions would not hurt the quality of the data while in theory increasing the completion rate of the survey. It would have been beneficial to collect demographic data from the GoPro users, but to increase the response rate as much as possible the demographic questions were not included.

In summary, the goal of improving the surveys was to increase the response rate by removing some of the hurdles of the initial survey. The surveys were made shorter and more to the point, and the demographic questions were removed to make the participants more comfortable with participating.

4.2 Data collection

A total of three different materials were used to collect data during this study. The first material is a number of online surveys, of which the initial survey was covered in the previous section. The other online surveys were meant for GoPro users, and lifelogging researchers and event organisers. GoPro users were selected as a target audience as they are similar to lifeloggers. They wear cameras on their body and capture a lot of images and videos. This makes their data similar to lifelog data, so they were included to supplement the collected data from the lifeloggers. The lifelogging researchers and events organisers were selected because they are experts in the field of lifelogging. They could provide insights from a different perspective and in regard to the tasks used in evaluation events.

The second material consists of semi-structured interviews. These interviews were conducted with some of the lifelogging researchers and event organisers who participated in the online survey. Additionally, the consent form used for the surveys and interviews is covered at the end. The third and final material is the review of academic events covered in Section 3. The surveys and their differences are explained first:

4.2.1 Online survey for GoPro users

The second online survey was sent to GoPro users. This survey was also created using the Qualtrics platform [19] using the license provided by Utrecht University. The aim of this survey was to supplement the data gathered from lifeloggers. The survey for GoPro users was added to the study after the disappointing response rate of the initial survey for lifeloggers. As mentioned previously, GoPro users behave and produce data similarly to lifeloggers. However, as these groups are not exactly the same any results or conclusions drawn from the GoPro users data will have to be taken with a grain of salt as they might not be applicable to lifeloggers. The following questions were used in this survey:

- How do you usually use your GoPro? (Multiple answers possible)

  - Hand-held or attached to a hand-held stick
  - Attached to my body (e.g. wrist, arm, head, helmet, chest)
  - Attached to a vehicle (e.g. bike, surfboard, snowboard, car)
  - Placed at a fixed location or tripod
  - Other, please explain:

- What kind of data do you usually capture? (Multiple answers possible)
  - Videos
  - Still images
  - Time-lapse videos
  - Other, please explain:

- Where do you store your GoPro images or videos? (Multiple answers possible)
  - In the cloud
  - On my hard drive(s) via a storage application
  - On my hard drive(s) in self-organised folders
  - I don't store images/videos
  - Other, please explain:

- Do you ever delete any captured images or videos?
  - Yes, I almost always filter out the ones I want to keep and delete the rest
  - Yes, but I only occasionally delete some
  - No, I keep everything I capture
  - Other, please explain:

- How often do you look at some of your captured images or videos?
  - Almost daily
  - A few times a week
  - A few times a month
  - A few times a year
  - Almost never
  - Other:

- Do you do anything else with your captured images or videos? (e.g. editing, creating video clips, sharing)
  - No, I usually just look at the raw data.

  - Yes, namely:

- Do you use any application or tool to access and browse your captured images or videos?
  - No, I access the data directly.
  - Yes, I usually use software and services provided by GoPro.
  - Yes, I usually us the following software or services:

- Do you ever search for particular images or information in your videos? (e.g. a distinct image or scene found in one video)
  - No, I hardly ever do that.
  - Yes, I do this occasionally.
  - Yes, I do this frequently.
  - Other, please explain:

- (Optional) Can you explain what you find most exciting/enjoyable when going through or searching in your captured images or videos?

- (Optional) Can you explain what you find most annoying/frustrating when going through or searching in your captured images or videos

4.2.2 Online survey for lifelogging researchers and event organisers

The third online survey was sent to lifelogging researchers and event organisers and was also hosted on Qualtrics [19] using the license provided by Utrecht University. The goal of this survey was to reach participants that are experts in the field of lifelogging and to extract insights on subjects that were not gained from the other online surveys. This resulted in a different view on the subject and on search tasks in particular. An example of this would be that lifelogging researchers have more knowledge regarding lifelogging technology and applications as they have worked with these during their research. This extra knowledge could provide nuance to the insights gained from the regular lifeloggers resulting in a broader, more general view of lifelogging as a whole and on search tasks in particular. This survey differs from the other two surveys in terms of questions and goals. This survey was less focused on the concept of lifelogging and more on the search tasks and evaluation events. The reason for this was that lifelogging researchers do not necessarily practice lifelogging themselves. However, a question was included which asked if they also practice lifelogging. This question then lead them to a survey for lifeloggers. The following questions were used in this survey:

- Most events related to lifelog research, such as the Lifelog Search Challenge (LSC) or ImageCLEFlifelog, focus on search in lifelog data. What do you consider the major search-related research challenges in relation to lifelog data?

- What do you consider the major non-search-related research challenges in relation to lifelog data?
- When evaluating multimedia search systems, we often specify tasks to test their performance. For example, the Lifelog Search Challenge (LSC) uses Known-Item Search (KIS) tasks. What do you consider the most relevant search tasks for lifelog data? (Multiple answers possible)
  - Known-Item Search (search for a specific image/event)
  - Instance Search (search for multiple, different examples of a person/activity/event)
  - Activity Detection (automatically detect activities in lifelog images)
  - Event Segmentation (automatically segment events in lifelog images)
  - Visualisation/Insight task (create visualisations/insights using lifelog data)
  - Other:
- The LSC simulates KIS tasks by showing textual descriptions of an event or image participants need to find. These descriptions are split into small chunks of text that are shown step-by-step. This means that the description becomes more detailed and accurate as time passes. Do you think this is the best way to simulate a KIS task for lifelog data?
  - Yes
  - No
- If not, how could the simulation of a KIS task for lifelog data be improved?
- Do you have any other comments on how the evaluation procedure at the LSC or related events could be improved?
- Do you practice lifelogging yourself?
  - Yes (regularly)
  - Yes (occasionally)
  - No

4.2.3 Surveys used in previous research

As covered in Section 2, Chen and Jones [12] have conducted previous research using online surveys on the subject of lifelog data usage. Their study was based on the use of non-lifeloggers as participants who were recruited via paid-survey services and social media. Their survey explored the type of lifelog data people want to capture and store, lifelog applications that they would like and finally the characteristics of the participants. Their survey was divided into three parts.

The first part asked participants if they ever wished to record or capture any of the lifelog data mentioned in the survey. A number of different lifelog

data types were included in these questions, while ensuring that not one type of data seems more important or useful than others. This was done via a closed question, which was followed up by an open question giving the participants an opportunity to reflect on the scenario presented by the survey.

Part two of the survey focused on capturing and using lifelog data. Participants were asked to rate capturing techniques on scale of 1-to-5 (where 1="don't want to capture at all" and 5="want to capture as many and as frequently as possible") and also to rate lifelog applications based on their usability on a similar scale (where 1="not useful at all" and 5="extremely useful"). After these ratings another open question was provided to let participants give suggestions based on the previous questions.

The third part introduced a prototype tool to access lifelog data. The prototype gave the participants an idea of what a lifelog system could look like. It was presented using a snapshot of the prototype with detailed instructions for all functions. The participants had to state which functions they could read and understand.

The survey ended with the collection of some personal details about the participants: Gender, age, how much they like their life being recorded, habits on deleting, organising and sharing, frequency of travel, and self-evaluation of their own memory. The results of the survey covered the quantitative features first after which insights gained from open questions were mentioned. Although the specific survey used in the study of Chen and Jones [12] was not included in their paper, their research provides a good example of using an online survey in this context. The study had 414 participants who provided a number of interesting answers to the open questions of the survey. The aim of this study was to acquire a comparable number of responses with equally useful insights.

4.2.4 Other existing surveys

Besides using previous lifelogging research as an example for the online surveys of this study other existing surveys were also looked at as examples. The use of (online) surveys is becoming more and more popular and accepted in scientific research and they are used frequently in the field of Human-Computer Interaction (HCI). Popular examples of these surveys include USE (Usefulness, Satisfaction and Ease of Use) [30], NPS (Net Promoter Score) [31], and SUS (System Usability Scale) [32]. However, most if not all of these surveys are based around closed questions and questions using (Likert) scales. While these questions and surveys are useful and valuable in their own way the surveys of this particular study focus more on open questions than on closed questions. Closed questions are not sufficient as they do not allow respondents to provide unexpected insights whereas open questions do allow this. These unexpected insights are incredibly valuable for this study to discover the major motivations behind lifelogging and the behaviour in regards to data usage and search tasks.

4.2.5 Semi-structured interviews

The last of the materials used in this study are semi-structured interviews, which were conducted with lifelogging researchers and event organisers. These participants were recruited using the online survey as interested participants could sign up for an interview. The semi-structured interviews were added to provide extra depth to the insights gained from the survey responses and to discover insights that were missed in the surveys, which could occur as the different methods of questioning can result in different insights being discovered.

The interviews had been prepared beforehand with the writing of an interview script to provide a general structure and flow to the interview. However, deviations from the script were possible and welcomed to ensure room for unexpected insights and topics. After a deviation the script was followed to ensure that all questions and topics are covered for each interviewee. A bias could have been introduced if the script was not followed anymore, which had to be avoided. The interviews were conducted virtually using Microsoft Teams or Zoom due to both the geographical location of the participants and the COVID-19 pandemic to ensure safety for the participants and researchers [33] [34]. The following script was used to guide the interviews:

- How often have you participated in the LSC?
  - In what years?
  - In what roles?
- Were you ever involved in setting up the challenge?
  - What role did you have? (e.g. system, data, tasks)
- Do you also lifelog yourself?
  - If so, how frequently? (e.g., regularly, occasionally)
  - How or where do you store your data?
  - How often do you access it?
- What do you think about the data set? E.g.:
  - Is it large enough?
  - Is it representative?
- What do you think about the use of expert and novice users? E.g.:
  - Should both be used or only one of these groups?
- How did you experience the usage of novice users? E.g.:
  - Was there enough time for them to get used to your system(s)?
  - Did you experience any problems with their usage?

- What do you think about the number of queries?
- What do you think about the way queries are currently done (i.e., as text queries that are expanded with more information over time)? E.g.:
  - Does this simulate a realistic search situation?
  - Could it be improved? How?
  - Should other representations be used (e.g., photos)?
  - What do you think about the duration for each query?
- Should other tasks be added to the LSC?
  - Which ones?
  - How could they be implemented?
- Can you think of any other research challenges beside "search" that would be interesting to address in a competition or workshop?

4.2.6 Consent forms

A consent form was presented to participants of each survey or interview, although the consent forms for the different surveys and materials were not the same. This section covers each different consent form.

Lifelogger survey consent form:

> Dear lifelogger,
>
> You are hereby invited to participate in a web-based online survey on the subject of lifelogging. This is a master thesis research project conducted by Ruben van Ettinger, a student of Utrecht University in the Netherlands. The goal of this research project is to investigate the practice of lifelogging. This involves researching the behaviour of lifeloggers via this online survey. You will be asked questions about your reason to lifelog, your usage of lifelog images, and your search behaviour when searching through lifelog images.
>
> Your participation in this survey is voluntary. You may refuse to take part in the research or exit the survey at any time without penalty. It is estimated that completing the survey will take between 5 and 10 minutes.
>
> You will receive no direct benefits from participating in this research study. However, your responses may help us learn more about the practice of lifelogging. There are no foreseeable risks involved in participating in this study other than those encountered in day-to-day life.
>
> Your survey answers are sent to Qualtrics.com where the data is stored in an environment protected by two-factor authentication and

only the researchers will have access to the data. The survey does not collect identifying information such as your name, email address, or IP address. Therefore, your responses remain anonymous. No one will be able to identify you or your answers, and no one will know whether or not you participated in the study.

Information regarding your age and gender is collected for demographic purposes and can not be used to identify you.

Please select your choice below. Clicking on the "Agree" button indicates that

- You have read the above information
- You voluntarily agree to participate
- You are 18 years of age or older

This was the first consent form made for this study and it was quite long and cumbersome. The subsequently used consent forms were made shorter and clearer to increase the response rates of the surveys.

Researcher and organiser survey consent form:

Dear lifelog researcher,

This is a survey about research challenges and current practices in lifelogging research, which is sent to active researchers in the field of lifelogging. It is part of a master thesis conducted by Ruben van Ettinger at Utrecht University in the Netherlands. It should take between 5 and 10 minutes to complete.

Legal disclaimer: Your participation in this survey is voluntary. You may refuse to take part in the research or stop at any time. You will receive no direct benefits from participating. There are no foreseeable risks involved in participating in this study other than those encountered in day-to-day life. Your survey answers are sent to Qualtrics.com where the data is safely stored and only accessible by the researcher conducting this study. The survey does not collect identifying information such as your name, email address, or IP address. Your responses remain anonymous and no one will know whether or not you participated.

Please select your choice below. Clicking on the "Agree" button indicates that

- You have read the above information
- You voluntarily agree to participate
- You are 18 years of age or older

GoPro survey consent form:

Dear GoPro user,

This is a survey about the use of egocentric cameras (such as GoPro). It is part of a master thesis conducted by Ruben van Ettinger at Utrecht University in the Netherlands. It should take between 5 and 10 minutes to complete. For related questions, please contact me via r.vanettinger@students.uu.nl

Legal disclaimer: Your survey answers are sent to Qualtrics.com where the data is safely stored and only accessible by the researcher conducting this study. The survey does not collect identifying information such as your name, email address, or IP address. Your responses remain anonymous and no one will know whether or not you participated. Your participation in this survey is voluntary. You may refuse to take part in the research or stop at any time. You will receive no direct benefits from participating. There are no foreseeable risks involved in participating in this study other than those encountered in day-to-day life.

Please select your choice below. Clicking on the "Agree" button indicates that

- You have read the above information
- You voluntarily agree to participate
- You are 18 years of age or older

Interview consent form:

This is an interview about research challenges and current practices in lifelogging research conducted with active researchers in the field of lifelogging. It is part of a master thesis conducted by Ruben van Ettinger at Utrecht University in the Netherlands. It should take a maximum of 30 minutes to complete.

Legal disclaimer: Your participation in this interview is voluntary. You may refuse to take part in the research or stop at any time. You will receive no direct benefits from participating. There are no foreseeable risks involved in participating in this study other than those encountered in day-to-day life. The interview will be recorded for the purpose of transcription. The recording will not be shared with anyone and will be deleted upon completion of the transcription. Your responses remain anonymous.

Please select your choice below. Clicking on the "Agree" button indicates that

- You have read the above information
- You voluntarily agree to participate
- You are 18 years of age or older

The biggest difference with the other consent forms is the fact that these participants have to agree to being recorded for the purpose of transcription. If they did not agree, the interview could still conducted with notes being taken instead of a recording being made.

4.3 Data analysis

The data analysis strategy is covered in this section. The data gathered during this study was predominantly qualitative data from survey responses and interview answers. Therefore, the process began with cleaning the data and coding the survey and interview responses. The goal of coding the responses was to make the qualitative data easier to handle and easier to analyse. The different steps of the data analysis plan are described below:

4.3.1 Data preparation

The first step after the data collection was completed was to clean the data. This meant removing any fake or impossible responses from the survey data and transcribing and cleaning the interview responses.

The survey data was cleaned in a number of ways. Especially the initial survey for lifeloggers resulted in quite a few empty responses, or in responses left by non-lifeloggers. The empty responses obviously did not result in any data and were therefore removed, while the fake responses did not result in data from lifeloggers and were removed for that reason. Besides this initial filtering, the rest of the survey responses were not cleaned or changed in any way to retain the integrity of the data.

The interview responses were also cleaned. As mentioned, the interviews were recorded for the purpose of transcription. Transcription software was used to conduct this process, as doing it in an entirely manual manner is too labour-intensive. However, the use of this transcription software in combination with the (relatively) low quality recordings resulted in occasional mistakes in the transcriptions. For this reason, each transcription was manually checked and corrected where needed. No data was removed from the interview transcriptions to retain the integrity of the data.

4.3.2 Coding the data

After the data was cleaned, transcribed, and organised it was time to code it. As explained, coding the data was needed to allow for easier qualitative and quantitative analysis. This section covers the different codes used to categorise the survey and interview responses.

Lifelogger survey As covered in Section 4.1.2, the initial survey for lifeloggers did not result in enough responses to warrant coding. The responses to this survey were looked at individually and, while analysis was not possible, a

few interesting insights were gained. These were also covered in Section 4.1.2.

GoPro survey The survey for GoPro users did result in sufficient responses and these responses were coded accordingly. These codes are covered in Tables 3, 4, 5, and 6.

Codes	**Number of appearances**
Editing	88
Sharing	57
Work related things	2
Data extraction	1

Table 3: Do you do anything else with your captured images or videos?

Codes	**Number of appearances**
Adobe suite	13
DaVinci Resolve	8
Native apps	3
GoPro software	2
iMovie	1
Luma	1
Sony Vegas	1
Final Cut	1
Avid Media Composer	1
Irfanview	1
VLC	1
Twitch	1
Thundersoft Video editor	1
VideoPad	1

Table 4: Do you use any application or tool to access and browse your captured images or videos?

Codes	Number of appearances
Reminiscence	26
Finding a great image or shot	12
Discovering something you missed in the moment	9
Sharing	7
Learning to become better at using a GoPro	2
Good video quality	2
Quick system response	1
Editing	1

Table 5: The most exciting or enjoyable things when going through captured images or videos

Codes	Number of appearances
Too much data	13
Software doesn't do what I want it to do	11
Data is not what I wanted (low quality, bad angle)	8
Processing the data is hard or cumbersome	8
Going through the data takes too long	4
Hardware doesn't do what I want it to do	4
Too much useless or redundant data	4
Naming the data is tedious	4

Table 6: The most frustrating or annoying things when going through captured images or videos

The remaining questions of the GoPro survey were closed questions that did not require coding in order to be used to conduct an analysis.

Researcher and event organiser survey The survey for researchers and event organisers also resulted in sufficient responses to warrant coding. The codes are covered in Tables 7, 8, 9, and 10.

Codes	Number of appearances
Query building	4
Feature extraction/detection	4
Similarity of images	3
Accuracy	3
Multi-modality of data	3
Supporting the search	2
Gap between images and semantics	2
Unstructured data	1
Data storage	1
Efficiency	1
Amount of data	1
Access to more data sets for evaluation	1

Table 7: Major search-related research challenges in relation to lifelog data

Codes	Number of appearances
Privacy	6
Data acquisition	6
Data quality/cleaning	6
Search system UI	3
Security	2
Data storage	2
Browsing/exploration	2
Lifelog summarisation	1
Lifelog analysis	1

Table 8: Major non-search-related research challenges in relation to lifelog data

Codes	Number of appearances
Start with full description	3
Reduce ambiguity of descriptions	2
Reveal more info after wrong submission	1
Add parts of the image to description	1
Fewer description steps but with more info	1

Table 9: How could the simulation of a KIS task for lifelog data be improved?

Codes	Number of appearances
Add visual KIS queries	2
Focus on science rather than fun	1
Ensure no groundtruth is missing	1
Use double blind evaluation	1
Use more experts & novices	1
Add an ad-hoc search task	1
Expand data set with more lifeloggers	1

Table 10: Do you have any other comments on how the evaluation procedure at the LSC or related events could be improved?

As with the GoPro survey, the remaining questions were closed questions that did not require coding.

Semi-structured interviews The semi-structured interviews, conducted with lifelogging researchers and event organisers, resulted in a high number of useful insights, which were coded as well. The codes used for these interview responses were more general than the previously covered codes. This approach was chosen as the interview responses were much longer and had much more information than the survey responses. Assigning the codes with the same level of detail as the survey codes would take too much time and not improve the data that much. Instead, the responses were organised into five categories of which three categories were divided into a *current state* and a *future state*. This was needed as the participants often offered their views on the current state of elements of the events, while also offering advice on the future state. These insights could be easily kept track of via this coding method. The used codes can be found below in Tables 11, 12, 13, 14, 15.

Codes	Number of appearances
Current state of the data set	15
Future state of the data set	12

Table 11: Interview responses regarding the data set used in the LSC and other events

Codes	Number of appearances
Current state of novices and experts	18
Future state of novices and experts	14

Table 12: Interview responses regarding the use of novice and expert users

Codes	Number of appearances
Current state of queries	16
Future state of queries	14

Table 13: Interview responses regarding the queries used in the LSC and other events

Codes	Number of appearances
Other tasks	10

Table 14: Interview responses regarding the potential addition of other tasks

Codes	Number of appearances
Other research challenges	4

Table 15: Interview responses regarding other research challenges that should be tackled in such events

As explained, these responses were not coded in the same detailed manner as the survey responses. Instead, the main goal of the coding was to organise the responses for easier comparison, counting, and analysis.

4.3.3 Content and thematic analysis

Following the coding process, the data needed to be analysed. This was done using two closely related analysis methods: content and thematic analysis. These methods are core tools when it comes to qualitative analysis.

Content analysis is defined as *a systematic, replicable technique for compressing many words of text into fewer content categories based on explicit rules of coding* [35]. Krippendorff proposes six questions that must be answered during every content analysis [36]. These questions (and their answers in relation to the interview responses) are found below:

1. Which data are analysed?
   (a) Interview responses.
2. How are they defined?
   (a) Only responses from interviews conducted during this study are analysed.
3. What is the population from which they are drawn?
   (a) The population is made up of lifelogging researchers and event organisers.
4. What is the context relative to which the data are analysed?

   (a) The context of the analysis is a study investigating the current academic events and the tasks used during these events.

5. What are the boundaries of the analysis?

   (a) The analysis is focused on lifelogging and the events and tasks related to this subject.

6. What is the target of the inferences?

   (a) The target of the inferences is to identify potential improvements to events and their tasks.

These questions and answers were kept in mind during the coding and analysis process to remain on course.

Thematic analysis is a method for systematically identifying, organising, and offering insight into patterns of meaning (themes) across a data set [37]. This method is focused on finding the broader themes across a data set, which was done following the coding process. The themes that were found were used to organise the results of the surveys and interview responses and form the answers to the research questions found in the scientific paper. The themes found when analysing survey and interview data from the lifelogging researchers and event organisers are:

- The data set is great and interesting, but we need more data or more lifeloggers to improve the evaluation.
- Semantics are the main issue when it comes to the queries.
- The split between novice and expert users is important. The procedure should be improved to reduce variability.
- Retrieval should remain the main focus, although other research challenges should be tackled in different events.
- The LSC is a fun event and potential changes should not reduce the fun.

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