Designing a User-Friendly Ski Film System

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Declaration

I, Michael Clark, declare that the material submitted for assessment is my own work except where credit is explicitly given to others by citation or acknowledgement. This work was performed during the current academic year except where otherwise stated.

The main text of this project report is 14,906 words long, including project specification and plan.

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Michael Clark (10/08/20)

Abstract

Humans have recorded events since 37,000 BP. In modern times, monumental and non-monumental events are constantly recorded through videos and pictures. A child's first steps, a graduation, or the completion of a marathon are as easily recordable as a selfie on the sofa or a picture of this week's grocery list. The skiing environment presents an area where memorable events remain difficult to capture. Handheld cameras such as the GoPro or smartphone cameras have made this recording easier, but as they are not designed specifically for the skiing environment, they still fall short of being "user-friendly". This project aims to tackle the challenges of designing a system capable of recording memorable events in a skiing environment in a user-friendly manner. The project follows a rigorous design process as well as usability literature, eventually producing a working prototype in the form of a series of cameras capturing footage directed by a location tracking mobile application. The success of the design is then evaluated in a subsequent usability study which assesses its success as a user-friendly system.

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1. Introduction

A skiing holiday is no exception to the fact that when people are creating memorable moments, they like to capture those moments to reflect on and share. However, unlike other memorable moments such as a child's first nativity, going to a football game, or visiting Disney Land, the landscape, environment, and nature of skiing makes capturing those moments incredibly difficult. Skiing is a fast and dangerous sport, carried out in extreme and treacherous conditions. In one sense this adds to the memorability of the events which take place, these out of the ordinary variables increase the worthiness of those memories being captured. However simultaneously, these variables make those memories more difficult to capture and make for a frustrating experience of using the existing solutions for capturing ski film.

This project focuses on designing and building a user-friendly ski film system by following a user-centered design process. The motivation for the project is that the current solutions for capturing skiing footage provide a poor user experience which results in memorable moments, which the user would like to capture, going uncaptured and being lost.

1.1 Problem Definition

Skiing on a ski holiday creates memorable experiences which have value in being captured through visual media. That value takes multiple forms: social and metaphysical value, esoteric technique analysis value, entertainment and enjoyment value, and economic value. However, the existing solutions for capturing skiing memories are impractical to use, ineffective in capturing memorable moments, and provide a frustrating user-experience. The culmination of these issues results in many memorable skiing experiences going uncaptured and becoming lost, taking with them the potential value they once held. The field of user experience and interaction design has developed alongside progressions in both software and hardware to provide the tools necessary to address these issues. Nevertheless, there has been no consequential work done to specifically apply these developments in the context of capturing memorable skiing experiences.

1.2 Objectives

This project aims to explore how HCI research and design principles can be used to design and build a system that can record video of skiers in action. The process focuses on research, design, software engineering, hardware development, and evaluation. The resulting prototype should creatively use hardware and software in a system which nullifies the user experience downfalls of existing solutions and satisfies user desires for future solutions.

Primary Objectives:

- Review literature, existing similar work, and research user-centered design techniques.
    - The scope of literature and existing similar work includes automatic sports filming and editing, as well as the psychological and social implications of memory capture.

- Conduct an early user study and evaluate existing solutions to determine a list of user requirements.
    - Existing solutions include the GoPro, mobile phone, and SkiLine SkiMovie.

- Based on user requirements, design and create a prototype ski film system for the purpose of ideation evaluation.
    - The differing extent that features need to be developed to allow prototype testing will be decided based on the early user study and methodology research.

- Conduct a usability study and evaluation of the prototype system against the user requirements.

Secondary Objectives:

- Create a set of design resources that can be used for the future development of this work.
    - Design resources may include research, recommendations, design guidelines, and a prototype amongst other possibilities.

1.3 Ethics

The early user study will involve both a questionnaire and interview. The evaluation study will involve an interview. Ethical considerations to be aware of include the holding and handling of data as research responses, as well as considerations regarding working with people who will be research subjects. This project poses no extra risk to subjects beyond what they expect in daily life. Ethical approval has been acquired by the application titled "Designing a User-Friendly Ski Film System" (Appendix A – Ethics Form).

1.4 Dissertation Structure

Chapter 1 – Introduction introduces the project's topic and scope, outlining initial objectives and eventual outcomes.

Chapter 2 – Literature Review contextualises the project based on similar work and usability literature that should be incorporated into the interaction design of an HCI system.

Chapter 3 – Design Methodology outlines each stage of the design procedure that this project follows.

Chapter 4 – Early User Study describes the design and findings of a study designed to discover a list of user requirements regarding ski film systems.

Chapter 5 – Design Process describes the design journey, tools used, insights, and design implications.

Chapter 6 – Final Design details the final design and how its features meet the user requirements identified in chapter 4.

Chapter 7 – Prototype explains how the final design translates to the prototype system and justifies the choice of feature development.

Chapter 8 – Usability Study discusses the design and findings of a study conducted to evaluate the usability of the final prototype system.

Chapter 9 – Conclusion assesses the success of the project against its objectives, project limitations, and future development.

2. Literature Review

The objective of this literature review is to establish an understanding of the key topics in the project, build an argument for necessity, and define the project scope. The chapter contains three sections.

The first section focuses on the necessity of a ski film system, specifically: the psychology of capturing memorable events, the economic implications of memory capture, developments in snow sport technique analysis, and the rise in snow sport popularity and implications for content creation.

The second section discusses the state of the art of ski film systems. It covers existing systems, the significant HCI usability aspects of those systems, and the latest developments in automatic video recording and editing.

Section three defines the scope of the project and its necessity.

Section One: Why a Ski Film System is Needed

2.1 Psychology of Capturing Memorable Events

Figure 1 Bison drawn in coal at Chauvet-Pont d'Arc [1]

Humans have used technology to capture memorable events ever since its' possibility. Chauvet-Pont d'Arc is world renowned for its Palaeolithic art dating back to 37000 BP, where smeared coal illustrations show groups of bison [1]. Since then, we have been capturing using every applicable technological from papyrus scrolls in 3000 BC Egypt [2] to camera phones. Capturing memorable events in one form or another is inherent in humans and ski film systems are one of several extensions to this tendency.

The broad motivations causing humans to keep capturing memorable events have remained consistent throughout time, despite circumstances and technologies developing. When focusing on visual memory capture motivations have social roots. Media is used as a form of memory support which is used to assist in evoking sensual memories at later dates [3]. Memory media is also used to maintain relationships as it acts as a reminder of past shared experiences and former close bonds [3]. Memory media is also used to define cultural membership, for example an image of a climber at the summit of Mount Everest is seen as a social membership pass into the extreme mountaineering club [3]. These social motivations of memory capture are consistently applicable to mankind regardless of the time-period chosen.

Figure 2 Climber posing on Mount Everest [6]

There are also individual motivations for memory capture through media. Firstly, memory capture through media is used for documentation, such as a family picture outside of a new home [3]. Outwardly, memory media can permit self-expression which "gives voice to one's unique view of the world". Similarly, memory media can be used for self-presentation as a tool to "influence others' views of oneself".

Regardless of intent or process, memory media has intrinsic societal use. As humans naturally continue to push limits such as freediving in space, and exploring the deepest sea shipwrecks, they create more memories which deserve capture. Further exploration into extreme conditions stimulates the need for technological development which can keep pace with this exploration and continue to allow memory capture. As skiing entails an extreme environment which is the site of countless memorable events, it is pertinent that technology is upgraded to allow the capture of these memorable events.

2.2 Business Implications of Memory Capture

Almost every business model attempts to harness and utilize memory capture for its array of marketing purposes. In the social media age, memory capture is a tool which can multiply the sentiment that a customer experiences when engaging with a product, brand, or service. Firstly, people are biased to only want to capture positive aspects of their memories as they wouldn't want to be reminded of negative experiences, thus when a memory is captured and subsequently reviewed in relation to a business, the user will only think of the positive aspects of this service [3]. Secondly, sharing memory capture acts as free advertising for the business, especially when that memory capture is positive [5]. Thirdly, for some brands, as a business-related memory capture is seen by more people it can create a social norm to be associated with that business or even exclusivity in being associated with that business [6]. The role that memory media plays in a business model cannot be understated as memory media can sentence a business to either wild success or utter despair. Ski resorts are businesses with needs to produce yearly profits. Thus, for resorts confident in their customer experience, systems which remind and share those experiences will be welcomed.

Figure 3 People on roller coaster in Alton Towers [9]

A subset of business sectors utilize memory capture as direct revenue generation. Amusement parks, stadium tours, and graduation photographers are all examples of business models where the memory media is a product to be sold. For example, Alton Towers sells a £20 pass for customers to access unlimited images of themselves taken on rides throughout the day [7]. At Tottenham Hotspur stadium tours customers can pay to take home a professional image of themselves with a player cropped in [8]. The formula behind each revenue generating memory activity is simple and repetitious, regardless of the business. Firstly, a memorable experience which a customer would want to remember is made. Secondly, the business must capture that memory in a way that the customer cannot do themselves, for example the Alton Towers cameras capture images during the rides, and the football fan cannot (without difficulty) take their own picture with a digitally imposed football player. Therefor a ski resort, as a place with experiences that people want to remember, would easily be able to

implement this practice with a ski film system which captures memory in a way which the skier alone cannot do.

2.3 Snow Sport Technique Analysis

Figure 4 Baltimore Ravens reviewing game footage [12]

Both professional and amateur athletes are constantly exploring how to improve themselves and their technique. A key tool is reviewing the technique, analysing it, and making improvements based on that analysis. In most sports this practice is commonplace and an essential part of improvement. In the NFL, film is an integral part of both pre-game preparation and post-game evaluation as teams study the plays and players of the opposing team [9]. Aside from monitoring tactics, film review is also exceptionally useful in refining technique due to its ability to slow down, pause, and rewind footage, giving the athlete previously unattainable perspectives. This was demonstrated through a series of ballet analyses, where performers could self-scrutinise their lifts to refine for perfection [10]. Furthermore, in sports where learning by doing can be physically risky, incorporating a learning by watching aspect can help mitigate that risk. For example, a learning by watching video technique was implemented to train rugby tackling which improved technique whilst avoiding injury risk [11]. A suitable ski film system would allow skiers to rectify any slights in their technique by gaining a perspective they hadn't seen before. However, the nature of the skiing environment being a gigantic mountain with difficult terrain and fast movements mean that the straightforward video capture methods used in other sports, such as simple static phone footage capturing, is unavailing.

Skiing attracts millions of beginners looking to learn the sport every year. However, there are factors unique to skiing which make the learning process exceptionally difficult. Firstly, skiers usually only practice their skills once per year during a holiday, limiting practice opportunity. Secondly, whilst practicing there is a high cost of failing as falling hurts and incurs recovery time. The sparse frequency of feedback, lack of real-time feedback, and delay in opportunity to implement this feedback makes improving skiing technique very difficult. Whilst a ski film system may not be able to give more regular practice opportunity or shorten the time it takes to implement new feedback; it could give learners a persistent reminder of the feedback they need to implement and technique they need to change. Therefore, a well-designed ski film system can greatly improve the learning experience for beginner skiers.

2.4 Snow Sport Popularity and Content Creation

Figure 5 Zeb Powell snow sport star [16]

The increase in snow sport popularity has allowed for "influencers" who rely on content creation to drive their following. Snow sport content creators are restricted in the types of footage they can garner, which restricts their ability to build a following. Olympian gymnast, Nile Wilson, has built a 1.5m YouTube following through producing a variety of gymnastic related content [12]. The stable environment and confined regions in gymnastics enables a variety of shot angles such as point of view, long range, short range, still, moving, and even aerial drone shots. This variety of shots makes Nile's content engaging and unpredictable, driving his popularity. In comparison Red Bull snow boarder, Zeb Powell, has built an 11.5k YouTube following [13]. In Zeb's videos he is constantly restricted to three shots, a point of view, a static pan, and a friend following shooting a moving pan. Both Nile and Zeb perform death-defying stunts in every video and have brilliant on-camera personalities, however their content quality is noticeably different. Whilst shot choice is one of thousands of variables determining YouTube following, snow sport content is limited to the shot angles available from existing ski film systems, and thus the influencer ability to grow is restricted.

Section Two: State of the Art of Ski Film Systems

2.5 Existing Ski Film Solutions

Mobile Phone

Most amateur skiing footage is shot using a smartphone due to their ubiquitous availability and high-quality features. Modern smartphones such as the iPhone 13 are equipped with a 12MP camera and video stabilization features [14]. Phone recordings take two forms; a skier can self-record a POV shot whilst skiing, or a friend can record the skier. Whilst smartphones are the most common form of recording ski film, they are not explicitly designed to be a ski

film system. Consequently, there are limitations when applying a smartphone to this use such as battery life, storage capacity, ease of use, shot availability, and ski disruption.

GoPro

A GoPro is a HD micro camera which is lightweight, small, and rugged [15]. A sturdy build makes it suitable for use in extreme environments. Users will usually attach a mount to the GoPro (such as a helmet, body attachment, handle etc) to allow point of view (POV) or self-recording [16]. The novelty of GoPro is the sensation of "being there"; the resulting video conveys the impression that the viewer is present in the action [17]. The GoPro is a general use action camera, meaning its scope includes recording from all other action activities as well as skiing. The balance between general and specified purpose means the GoPro is not designed to be the optimal ski camera, despite being most associated with ski film recording.

SkiMovie Tracking Installations

Tracking installations are the latest innovation in ski film recording. Most notable is SkiLine SkiMovie (2010). The SkiMovie concept is to limit access to a small slope, allowing one skier at a time. Footage is then recorded by a permanently installed pan-tilt camera system which motion tracks and follows the skier [18]. The novel aspect of SkiMovie comes in two forms, firstly the shots captured are at an angle which is difficult for a skier to obtain. Secondly, the recording is effortless as the skier must only tap an RFID pass and ski, eliminating need for camera setup and adjustment. As a purpose-built ski film system, the concept and design of the SkiMovie system is an improvement due to the intended ease of use and simplicity. However, the implementation leaves significant shortfalls such as lagged shots, limited slope options, and number of rider limitations which are covered in the following section.

An example SkiMovie clip can be found here: https://www.skiline.cc/video/3u70hi?cid=6465320

2.6 HCI Usability Aspects of Existing Systems

This section will critically evaluate existing solutions from a HCI usability and general performance perspective. For each device the user experience will be evaluated, followed by a review of the general output, and finally the devices' role in the wider process of recording a skiing video to share.

User interaction with the GoPro shares similarities with the user-smartphone interaction. Both find device placement, being held or mounted, press record and at the end of the slope stop the recording. The skier then transfers the footage to a computer and edits it (or edits the footage directly in the phone) before viewing and sharing it. Both devices give some visibility of the system status [19] that the device is recording, the phone an intuitive display change and the GoPro turns on a light which can leave an inexperienced user confused. Both devices adhere to Neilson's [19] guidance of matching the system to the real world as they contain screens which show the current frame. However, this can be redundant as error prevention [19] is low in both the GoPro and smartphone. Users can easily mount or hold each device in a suboptimal position or begin recording accidentally. Neither system shows adherence to Schneiderman's rule of helping users recognize, diagnose, and recover from errors [20] to alert them to this.

The GoPro and the smartphone can cater to recording in many environments. This is a positive general product feature; however, a drawback when sole use as ski film system. Firstly, the portability of the cameras mean that the user is limited to handheld and POV shots when recording whilst skiing. Secondly, the devices adaptability means that the hardware is not optimal for skiing conditions, making it difficult to adjust camera settings as doing so entails removing gloves during an extreme cold. However, the hardiness of the GoPro build does make it suitable for use which cannot be said for smartphones. Both cameras provide instant footage reviews with onboard screens which improve learnability, feedback, and show a match between the system and the real world [19]. Furthermore, smartphone footage can be edited and shared from the device, making the process particularly efficient [19]. The GoPro, however, follows an arduous process of transferring footage to a computer and editing it with video editing software to render a desired form. Small screens on both devices means that visual on-screen elements must be restricted to save space, this increases the short-term memory load required as settings are less obvious, especially when used infrequently [20].

The video captured by GoPro and smartphone pose varying satisfaction levels [19] depending on user expectation. The GoPro allows the user to be immersed in the footage which has built in stabilization and HD imagery [15]. However, as a purpose-built action camera, user expectations are greater and thus harder to meet. On the contrary, the smartphone footage is poorer quality, however its accessibility and convenience makes it on par with expectations.

The interaction between the user and SkiLine is minimal, and this is to the benefit of the user. The user simply taps their RFID ski pass to a detector, and ski's down when allowed. Later the skier can type in their ski pass number and view the result. This simple system is easily learnable and efficient [19, 20]. There is small potential for user error as ski passes may go missing or get thrown out by the time the user wishes to view the video, however for the conscious user this is a non-issue. There is no feedback that the system is working properly as the user uses it, and if the wrong order of passes is swiped there is no going back – both of which are violations of visibility of system status and easy reversal of actions [21].

The video result of SkiLine leaves room for improvement. The motion tracking camera can be nauseating for viewers and leads to long, especially as at times the camera will lag and jerk to catch up with the location of the skier [22]. The motion tracking idea also leads to few long and continuous shots which are far away from the skier. This could be useful for a skier looking to critique their pathway down a slope, however it is likely perceived as boring and impersonal for a skier looking for an exciting clip to share or to really analyse technique. SkiLine accomplishes the goal of capturing ski footage, however it falls short of capturing meaningful memories. This is due to a multitude of reasons. Firstly, only allowing one skier at a time eliminates memorable group runs (however one person per ride is needed for its motion tracking to work). Secondly, SkiLine is only available on one slope whereas the GoPro and phones can be used on any slope, limiting the variety of footage a SkiLine can capture. Finally, because SkiLine is only able to record one designated beginners' slope with one skier at a time, it misses out on capturing the impromptu and unpredictable moments which are most desirable to capture.

In the wider process SkiLine is very effective. The SkiLine system facilitates recording, editing, and has easy options to access and share the result, showing good efficiency [20]. Therefore, the holistic experience of using SkiLine to capture skiing footage is so simple and easy, that satisfaction is attainable [19] despite a poor-quality output as users have not sacrificed anything to use the system.

2.7 Latest Developments

This section gives an overview of recent developments in automatic recording and a brief overview of automatic video editing developments. The purpose being to assess their suitability for purpose for ski film systems and this project.

Automatic Recording Developments

Automatic sports video recording has seen an increase in exploration over the past decade due to more powerful computers which are able to render higher quality content, increased accessibility to high quality cameras, and an improved infrastructure which stimulates both supply and demand of sports video content. Despite there being few developments explicitly in snow sports, technology tested with other sports could have crossover functionality.

Automatic sports video recording often relies on motion tracking, usually through video analysis, which is then used to directly command which camera is being used. Wang et al [23] created a system comprised of eight still cameras streaming one football game. Each camera is positioned at a different angle to watch the game, and the system tracks the ball location to automatically switch the camera view being streamed. Similarly, Ariki et al [24] created a system where situations such as penalties and freekicks were automatically detected through further ball analysis (location and time spent at location). Fujisawa et al [25] used ball tracking in the more structured baseball setting to detect a specific event, such as a pitcher about to throw, which triggered an automatic still camera for that event. Motion tracking is suitable for examples where there is one key subject that the camera must focus on, oftentimes being a ball of some sort. The key limitation that the motion tracking in these projects presents is that it can only be used for one subject at a time. Depending on the objectives of the system, one subject at a time could cause limitations to the usability of that system.

Aside from automatic sports recording, there have been developments in the automatic recording of animal behaviour [26, 27] as well as lecture capturing [28, 29]. Similarly, to the automatic sports recording, both rely on motion detection and tracking to trigger one of a set of cameras. A slightly different approach is to use one moving camera, such as the SkiLine, which continuously tracks a subject. The use of a single camera which can move freely has mostly been explored using drones. Benhadria et al [30] models landscapes and obstacles whilst a drone is in flight to allow it to navigate a clear path whilst following a motion detected subject. As a ski film system, this approach could be very useful as a drone could follow and record a skier, whilst mapping and navigating obstacles such as trees, poles, and other skiers, to maintain a smooth flight.

Automatic Editing Developments

Automatic video editing has been explored using a multitude of techniques. Huang et al [31] uses the loudness, pitch, and timbre of audio from tennis matches to automatically detect highlights and edit the video accordingly. Bhalla et al [13] uses a combination of audio detection and optical character recognition to extract important events in cricket matches such as boundaries and wickets. Chakraborty et al [33] takes a different approach by analysing the facial expressions and heart rates of viewers to automatically detect interest evoking video segments. The approach of monitoring one variable (such as sound) to edit video is

interesting and could have cross over into a ski film system, where a variable such as speed or heart rate could be used.

Section Three: How this Project will attempt to Solve

2.8 Project Necessity and Scope

Systems for recording skiing footage have been designed and implemented, such as the GoPro, smartphone, and SkiLine SkiMovie systems. However, these systems are limited and produce fluctuating results. The GoPro produces high quality POV footage when used correctly, however a poor user experience makes it difficult to use correctly in a skiing environment. Furthermore, the limitation to POV shots and difficulty of transferring that footage to a shareable format leaves dissatisfaction. The smartphone produces quick results which are easily shareable. It is a quick, easy, and available option. Similarly, to the GoPro, limitations on shot variety restrict the ability of the phone to meet user requirements. Furthermore, the smartphone not being built for purpose, safety considerations, and bothersome process in which recordings must take place results in a sub-optimal user experience which hampers the real experience of the activity at hand. Finally, the SkiLine system concept has potential for a great user experience; simple RFID identification, motion tracking, and an accessible webpage interface makes for a seamless user journey. However, the resulting SkiLine footage is both jagged and nauseating, impersonal, and restricted to a prescribed setting with room for one user at a time, meaning the footage it does capture is not particularly memorable or useful for the user. Due to these drawbacks in existing ski film systems, there is a need for an improved ski film system which incorporates a user experience design focus and automated recording technology to produce a high quality, memorable video result alongside a frictionless user experience.

This project will aim to design a ski film system which improves upon the existing ski film options in both output quality and user experience. It will do so by taking a user centered design approach. The focus of the design is usability, as this is the greatest shortfall of existing solutions. Technical nuances of automatic film recording, and editing are not the focus of this project, however their nuance will be used in creating user-centered designs.

3. Design Methodology

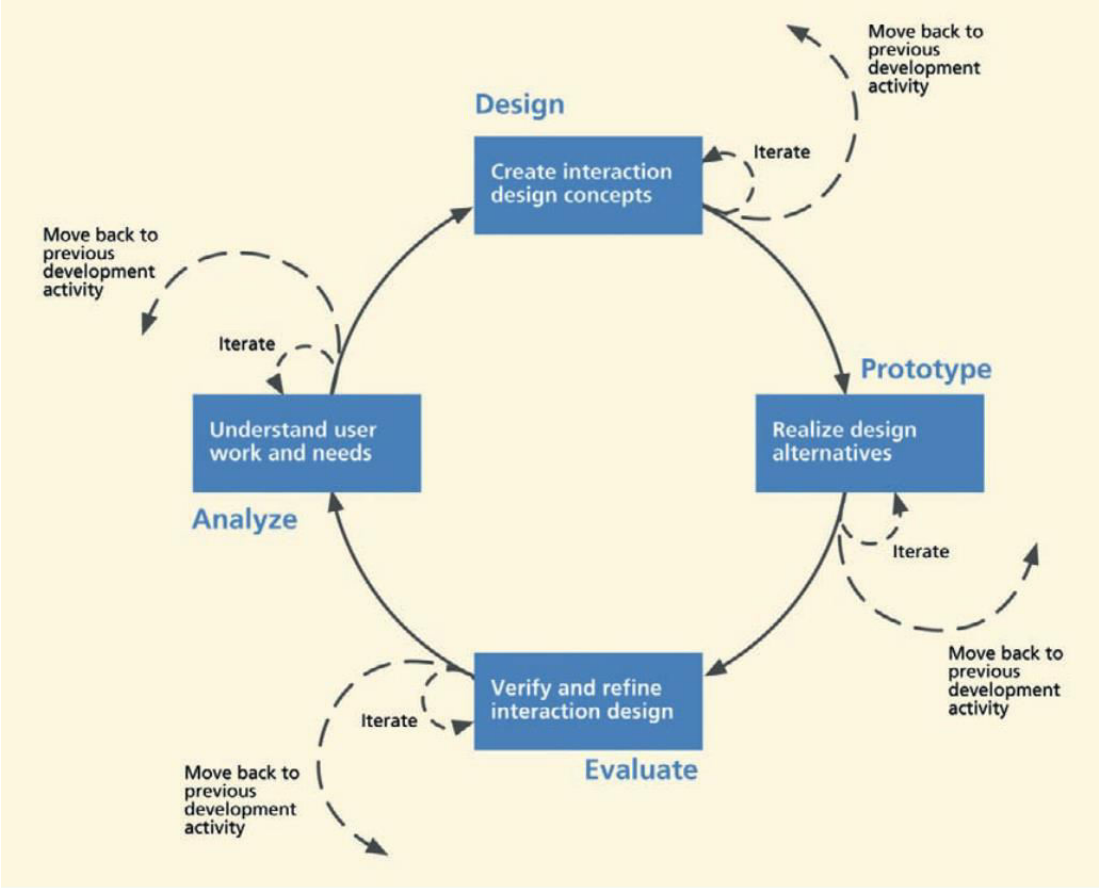


Figure 6 The Wheel design lifecycle [39]

This project implements one loop of a user experience (UX) design lifecycle termed "The Wheel" [34]. The Wheel is a design process which incorporates tools and frameworks at each stage to ensure a quality user experience is designed. This project uses both methods explicitly prescribed for The Wheel as well as other design tools which fit into the framework. The process began with a general hypothesis of user problems and followed four work stages to define those problems, ideate solutions, and refine a final design.

3.1 Stage One: Analyse

The analyse stage is intended to gain understanding of the domain, user work, and user needs of the project. This understanding was gained by through two activity sets: contextual inquiry (Appendix B – Early User Study) and contextual analysis (Appendix C – Data Models).

Contextual inquiry was used to understand the user work that the design is to support [34]. Data elicitation took the form of an "Early User Study" (Chapter Four). Contextual analysis was then used to make sense of the raw contextual inquiry data. The initial raw survey and interview data was combed for meaningful quotes which gave insight into user's thoughts, behaviours, and actions. These quotes were organised using an affinity diagram method which allowed key themes to be established [35]. Using the organised data, several models and frameworks were constructed to gain further understanding.

User personas were created depicting the average intended user [36]. User stories were written of a user's experience throughout a day of skiing [37]. Using the user stories and raw data, a task sequence diagram was constructed, describing the process of gathering ski film footage with a GoPro [34]. Finally, a system flow model [34] was created to illustrate the flow of data from a memory being captured, transferred, edited, and shared through existing technologies. Through the construction and analysis of these models and diagrams, understanding of the user, the context and the problem set clarified. Contextual analysis led to a set of defined user requirements.

3.2 Stage Two: Design

The design process (Appendix D – Design Process) began with a design board [38] comprising of artefacts such as skiing photos, ski lift passes, skiing videos and photographs, GoPro mounting instructions etc. An adaption of the 10 for 10 brainstorming method [39] was then used to spur a boundless creative process around generating initial ideas. A sketch tree diagram [40] was also used to explore themes of the work and illicit creative ideas by imposing certain restrictions. As designs showing potential became more obvious, they were explored further by using sequence sketches [34] to model their intended use and hybrid sketches to model their implementation in the real world. Throughout the design process, designs were presented to a design critique group [41] to gain valuable feedback from peers. Where possible, feedback was incorporated into new and adapted designs as part of an iterative process.

3.3 Stage Three: Prototype

The prototype stage (Appendix F – Prototype Build Instructions) was done in conjunction with the design stage [34]. This allowed different design ideas to be explored in ways which suited them best. Throughout the design stage ideas were constantly being evaluated and adapted based on how well they met the identified user needs. When designs showed to be a good fit for those needs and indicated a suitable degree of technical and commercial viability, they were made into different prototyping types. Digital paper interfaces [42] were made for digital interactions such as an app or web interface. Initially, horizontal "wizard-of-oz" type prototypes [34] were constructed for demonstration and understanding purposes before a final design (Chapter Six) was chosen and designated features of which were developed as a high fidelity, vertical prototype [34] (Chapter Seven).

3.4 Stage Four: Evaluate

Evaluation took the form of a "Usability Study" (Chapter Eight). The goal of which was to see whether the final design (Appendix E – Final Design) – represented by the final prototype – met the user requirements set out in the contextual analysis.

3.5 Sketching and Prototyping Tools

The tools used evolved as the design process evolved, reflecting the increasing fidelity of the prototypes throughout the process. Affinity diagramming was done using a Miro[1] board. The

[1] https://miro.com/

digital Miro board had a multitude of sticky notes in various colours, is cloud hosted, and can be navigated easily with zoom in and out functions. This made organising lots of raw quotes more streamline as colours were used to represent themes. The board could also be revisited, added to, and transported, making it a suitable design tool in a process where there was already lots of existing paper.

Pen, paper, and cardboard was used throughout the process. In brainstorming activities, it allowed the free-flowing organisation of ideas without the need to digitally arrange them. Pen also made idea sketching faster and allowed a more accurate representation of the idea to be depicted. When prototyping, paper and cardboard were used to model the environment and the hardware casing that users would be interacting with. Paper and cardboard allowed a surprising amount of flexibility and their low cost meant designs could be mocked up without worry that resources would be wasted.

To represent digital interactions, Balsamiq was used as a digital wireframing interface. Balsamiq[2] was chosen because of its fast and easy representation of ideas. This was important because it meant ideas were not being disrupted which being recreated from the brain onto the screen. Figma[3] was then used to further develop the the app aesthetic.

Chapter Seven describes the final prototype. In short, it used Expo[4] to build a mobile application, a Raspberry Pi with camera[5], a GoPro[6] and JavaScript and Python code. Expo was chosen as it allowed seamless application testing on a phone via WIFI and the existence of the Map View and Location Expo libraries.

[2] https://balsamiq.com
[3] https://figma.com
[4] https://expo.dev/
[5] https://www.raspberrypi.org/
[6] https://gopro.com/en/gb/update/hero4

4. Early User Study

This study was conducted under the ethics application titled "Designing a User-Friendly Ski Film System" (Appendix A – Ethics Form). The early user study was the preeminent activity to support the data elicitation stage of the design process. There were two aims in this study; The first aim was to gain a comprehensive understanding of user perspective and sentiment surrounding ski film systems, including existing ski film systems and the general concept of ski film systems. The second aim was to explore the user perspective of the general skiing activity and associated travel. Both aims would be used to fulfil the objective of this study, which was to derive a set of conclusions in the form of design principles. These design principles would be used to guide the design process of the new ski film system and a loose criterion against which the resulting design would be evaluated.

4.1 Study Design

The study was split into two activities: an online questionnaire and a series of interviews (Appendix B – Early User Study). The online questionnaire was created using Qualtrics and it consisted of open-text responses and matrix style Likert questions. The purpose of open-text responses was to accommodate for the inevitable unforeseeable answers when attempting to understand user emotions and discrete experiences. The matrix style Likert questions were used to gain qualitatively comparable information which could be used to easily understand user preferences. Qualtrics made it easy to distribute the interview and collect anonymous responses. Furthermore, the automatically interactive formatting and customisable question flow meant that the user experience of taking the survey should be less of an inconvenience to participants, which captures more meaningful responses.

The interviews were conducted in a semi-structured format, hosted virtually over Microsoft Teams[7] calls. A semi-structured format was chosen due to the impossibility of anticipating participant answers ahead of time. By using a semi-structured format, the interview had pre-set key themes to touch on but also left freedom to explore unanticipated aspects of those themes. MS Teams was appropriate because it allowed the recording and transcription of responses, allowing the interview to flow naturally without disruption for notetaking.

Both questionnaire and interview activities were designed to begin as general as possible, and to slowly become more specific. This would allow more general feelings and ideas to be expressed freely, before being reminded of those specific solutions which could restrict their ability to think openly after being thought of. Beginning with questions revolving around recent ski memories, the participants were given a chance to become reacquainted with a memories and experiences which are heavily removed from day-to-day life. These questions both acted as "warm-up" questions, reminding the user of their experiences to allow more insightful answers further in the activity, but also these questions around ski memories revealed which ski memories first came to mind for our participants, which can be telling of which memories are most significant for themselves as skiers. The second section consisted of questions regarding feelings before, during, and after the skiing trip. This would be useful in understanding the mindset of a participant at each stage through the skiing journey. The third sections discussed the concept of ski film systems in general such as what is the role of

[7] https://www.microsoft.com/en-gb/microsoft-teams/log-in

a ski film system, how might it be useful, and what parts of skiing would be best captured. The final section focused on the specifics of existing solutions, exploring what the participants liked and disliked about these solutions, what made them choose these solutions, the extent to which those solutions satisfied their purpose, and what could be improved upon in those systems.

4.2 Findings

The following section describes the findings from both activities outlined above. It is organised by the design principle themes which presented themselves throughout the study.

1. **The system creates holiday souvenirs.**

User intention with the resulting video spurred multiple interesting use cases. However, designing for multiple use cases would detract from the system effectiveness of designing for one use case. Some alternative use case responses included racing tracking, automatic technique analysis, feedback for resort improvement, and educational purposes such as teaching technique to children. However, the overwhelming use case response revolved around a holiday souvenir. Quotes such as "I would use video to show my parents", "it's something to hold our memories", and "I would like it just for fun" encapsulate most use case responses. Despite other use cases still being possible under a souvenir design, to be able to design the optimal user experience it is sensible to primarily focus on one use case.

2. **There should be three recording subjects: individual skier, group skiers, and the natural surroundings.**

Respondents showed little interest in recording subjects such as equipment (for performance analysis) or life outside of skiing (sight-seeing and general activities). Responses such as "I would want to see me and my friends skiing" and "it's difficult to describe the slope surroundings to a friend who hasn't been before" showed that the focus of the participants is almost exclusively on the actual skiing rather than any other aspect of the trip.

3. **The recording of significant, capture-worthy events should be prioritised.**

There is a significant preference for the recording of certain skiing aspects and a neutrality towards others. Participants specified moments such as jumps, falls, group sequences, and faster segments as events which they would like to be recorded. Participants showed little interest in having footage of general or "non-exciting" moments such as general touring and easier runs.

4. **User responsibility should be minimised at every stage of the user experience.**

The design of this system involves a positive relationship between user control and user responsibility. For example, heightened user control could include things like choice of camera, camera settings, and choice of shots. However, these come with the added user responsibility of packing a specific camera, being knowledgeable about camera settings, and being conscious of shot choice. Participant sentiment consistently indicated that a lack of control would be preferred when it also means a lack of responsibility. Before the trip, participants already felt nervous and anxious about travelling, therefore they wouldn't want the added responsibility of having to remember an extra item. During the skiing, users having the control of creating GoPro shots comes with the unwanted responsibility of setting up the equipment, remembering to record, charging the camera, and emptying the storage card.

Following the activity, existing options such as the GoPro require the user to edit the footage to turn it into the final form. However, this is a responsibility which participants neither want nor to achieve. Therefore, each stage of the user experience should aim to minimise its dependency on the user doing anything at all, and when the user does have to do something, it should be as simple as possible. This will allow for the seamless, responsibility-free, and error-avoiding user experience which participants indicated preference to.

5. **The system should minimize disruption of the normal skiing flow.**

A key annoyance with existing systems is the disruption to the skiing flow. Participants describe having to stop skiing to set up a camera, ensure the desired shot, plan out where group members must start from and so on. They explain that this disrupts the normal skiing experience which is their primary objective. The task of recording each other using existing solutions detracts from the experience of skiing, such as the recorder missing out on being in shot, the recorder having to focus on the shot rather than the skiing, the subjects of the shot being conscious of being recorded, therefore making the content of the shot not particularly memorable. When participants having finished skiing, they would rather follow the flow of being able to relax and recover in the evening rather than worrying about emptying storage cards and charging cameras. It is important to recognize that the participant's primary objective is skiing, not creating a ski film. Therefore, the less disruptive the ski recording, the more the user is able to enjoy the skiing.

6. **The quality of the footage should be as high as possible.**

Output quality was a consistently fluctuating factor for users which had significant weighting as to whether the result was usable or not. Participants described capturing vibrating, out of focus, and off-subject footage which they determined as unusable. Not only is there frustration with this quality of result after a tedious user experience in achieving that result, but a poor quality, unusable result also renders the user goal completely unfulfilled. If a system can maintain a consistently high quality, then the user experience will improve as the user goal is fulfilled.

7. **The result must be easily shareable to outside the system.**

The most popular use case for the skiing footage was as a holiday souvenir, with participants describing their intentions with the results as "sharing with friends", "posting on social media", "showing my parents", and "watching myself back". The social element of sharing the result was shown to be important for all participants, therefore the most satisfying user experience will make sharing the result simple and straightforward.

5. Design Process

This chapter is a continuation of "The Wheel" [34]. The previous chapter (Early User Study) covered data elicitation which is progressed in this chapter through data analysis. In Data Analysis (5.1), the data gained from the early user study is modelled and analysed to derive insights which then dictate specific design features or ideas. Data models can be found in Appendix C – Data Models.

With these ideas in mind, the ideation section of the design process begins with the use of a design board, brainstorming, and idea tree. The most promising ideas are developed and explained in Early Designs (5.2). This section resolves by choosing one design to develop further, based off of its adherence to the user requirements (4.2) and insights derived from Data Analysis (5.1).

The chosen design is then refined in 5.3 by exploring system interaction and editing possibilities. 5.4 explains the development of the mobile application design through the subjects of error prevention, system visibility, and app aesthetic. The culmination of this design development is discussed in Final Design (Chapter 6).

5.1 Data Analysis Insights

Group and social aspects should be given importance in design. Many of the models revealed a consistent theme of socialising and group activity being a key element of ski filming. The WAAD showed that people's most memorable memories involved others, whether that be skiing and doing tricks together, or singing on the chairlifts together. User stories showed the importance of family group recordings as well as user's main use for memory capturing being to share those memories with others (both present and non-present). The system flow revealed that the end goal for the resultant footage is often a place on social media, whether that be directly sharing with people via WhatsApp or Facebook Messenger, or to be used to build a profile, as seen with Instagram posts and Reddit posts. These findings suggest two features to be mindful of. Firstly, the system must work to not only capture individual skiers, but also groups skiing together. Secondly, the system should be optimized for easily sharing the resulting videos via social media channels.

Skiing should not be disrupted to capture footage. Interview quotes organised in the WAAD evidence a strong user pain point around how existing ski film systems heavily disrupt the user's primary objective, which is to ski and have a fun time. Demonstrated by task sequence and system flow diagrams, existing ski film systems require lots of setting up, adjustment, and disruption to the skiing experience. This can be in the form of battery and storage maintenance, mounting preparation, stopping to film shots, and repeating runs to reattempt shot capturing. The system design should be mindful of requiring the minimum user effort.

The user should always be aware of the current state of the system. A key issue with existing filming systems is the lack of system status visibility. WAAD user quotes and GoPro usage scenarios demonstrate users struggling to recognise whether a camera is recording or not, the shot that the camera is picking up, and the battery and storage statuses of the camera. This is exemplified by the work environment model, showing the added challenges of interacting with sensitive technological systems in exposed environments, whilst wearing

protective clothing. The result of poor system visibility in this difficult environment is memories going uncaptured, poor-quality film being captured, and the user experience turning to one of frustration rather than exuberance. This design process should explicitly identify what the user needs to be aware of and should then make this obvious.

Opportunity for user error should be minimised. Task sequences, and data flow diagrams showed multiple opportunities for user error which were confirmed in the WAAD and GoPro usage scenario sketches. These potential user errors spanned across the entire process of using existing systems; before a trip users can forget batteries, SD cards, mounts, and adapters. During a trip users can use the camera settings incorrectly and set up the mounting incorrectly. After the trip, the user can have issues with transferring footage to from camera to computer and using an editing program to output a format suitable for their needs. All these opportunities for user error represent barriers which users must overcome in achieving their desired goal, each barrier increasing the difficulty in achieving that goal. This system design should be conscious of the entire usage process and aim to minimise opportunity for user error at every stage of that process.

Simple and dependable is preferred over intricate and customisable. Existing recording options offer a multitude of possibilities in their usage. There are different ways cameras can be mounted and held, different configurations of settings, and different editing methods and outputs. This level of customisation is needed when designing a film system which can have multiple uses in multiple sports, or when the target user is a cinematography expert. However, when designing a system specifically for skiing with target users who are not cinematography experts, the array of intricate customisation options can lead to fluctuating results. This system design has a specific environment, user base, and usage to cater for, therefore many of the customisable options seen in existing filming systems can be replaced by built in features which result in a more dependable user experience.

The desired events to be captured are diverse. WAAD quotes and user scenario sketches revealed that the events which users want to be captured and want to share are diverse. Users want to capture group skiing, jumps, tricks, difficult segments, speed segments, scenic segments, amongst others. These events take place in different locations on and around the ski slope, they can also be the result of spontaneous actions and unpredictable or unexpected variables. Existing filming options such as a GoPro or mobile phone are extremely adaptable, making them suitable for recording an array of different events. However, design aspects such as their setting up requirements and operating requirements act as drawbacks when trying to record some of these events. This design should not only have the capability of capturing all the skiing moments that users desire to be captured, but it should also actually capture those moments without the need for extensive user preparation.

5.2 Early Designs

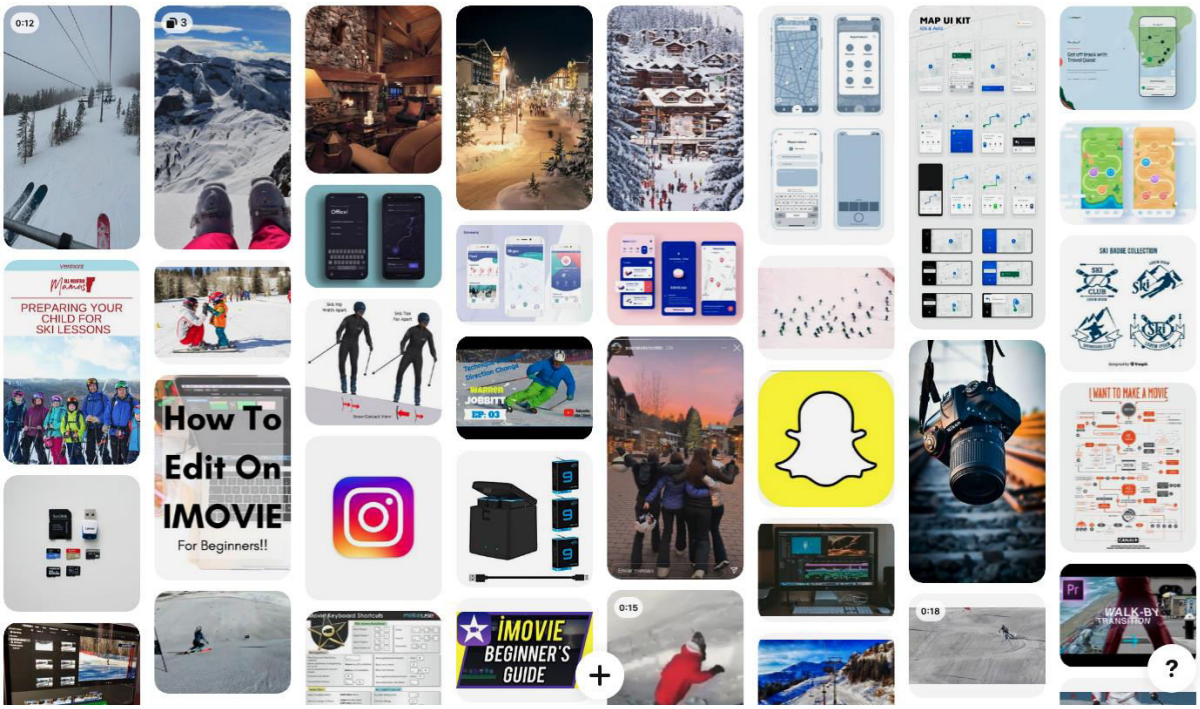


Figure 7 Design board made using Pinterest

Ideation began with a design board, an idea tree and brainstorming. The design board was used to draw inspiration and insights from existing and similar system. The idea tree was used to explore different themes and ways they could be implemented. A brainstormed mind map was used to consider user issues and how they could be nullified through design. Design Process artefacts can be found in Appendix D – Design Process.

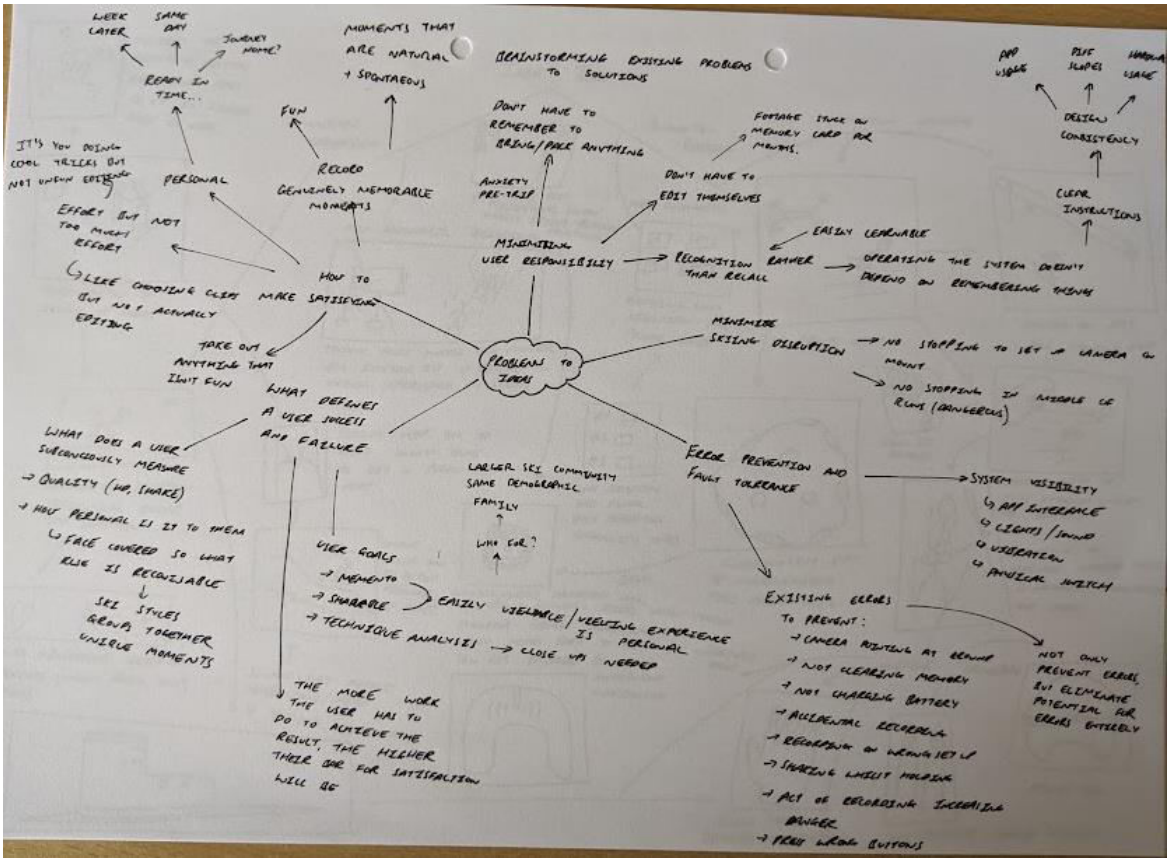


Figure 8 Ideation Mind Map

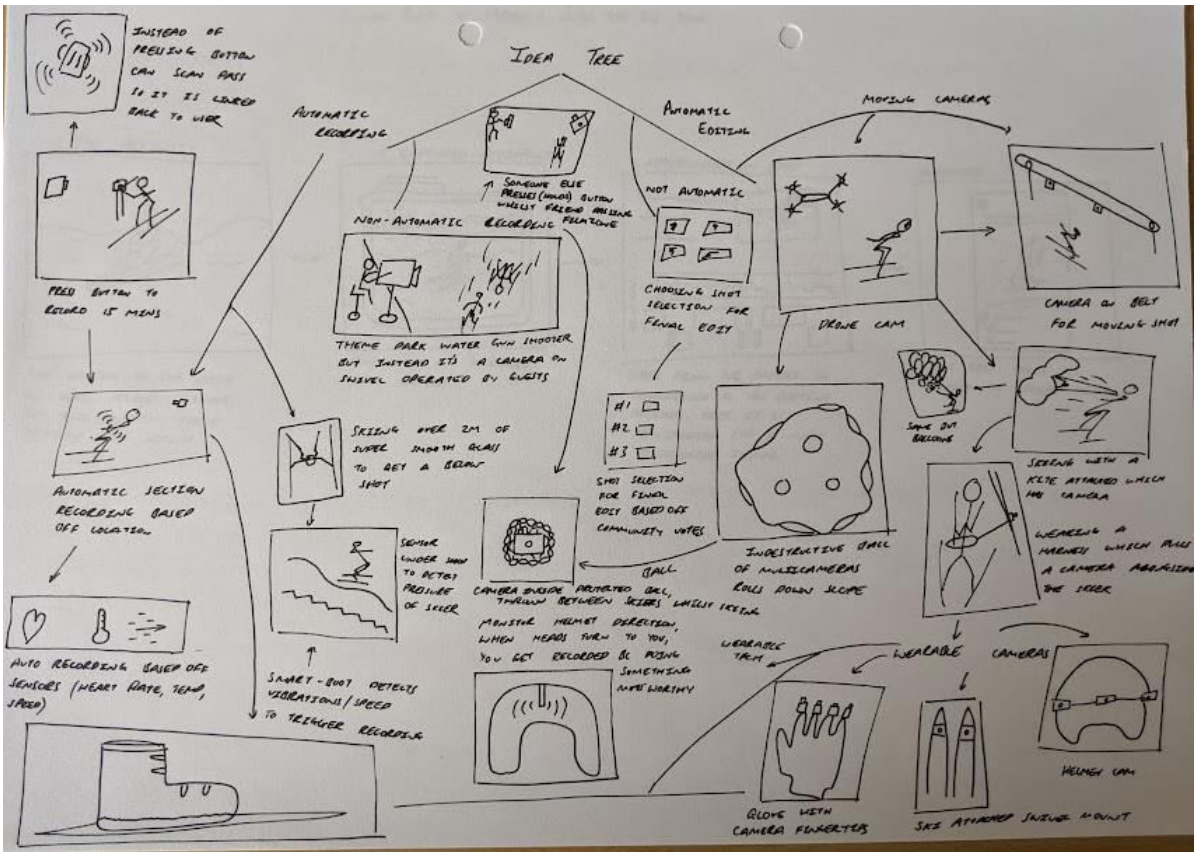


Figure 9 Ideation Idea Tree

Helcam

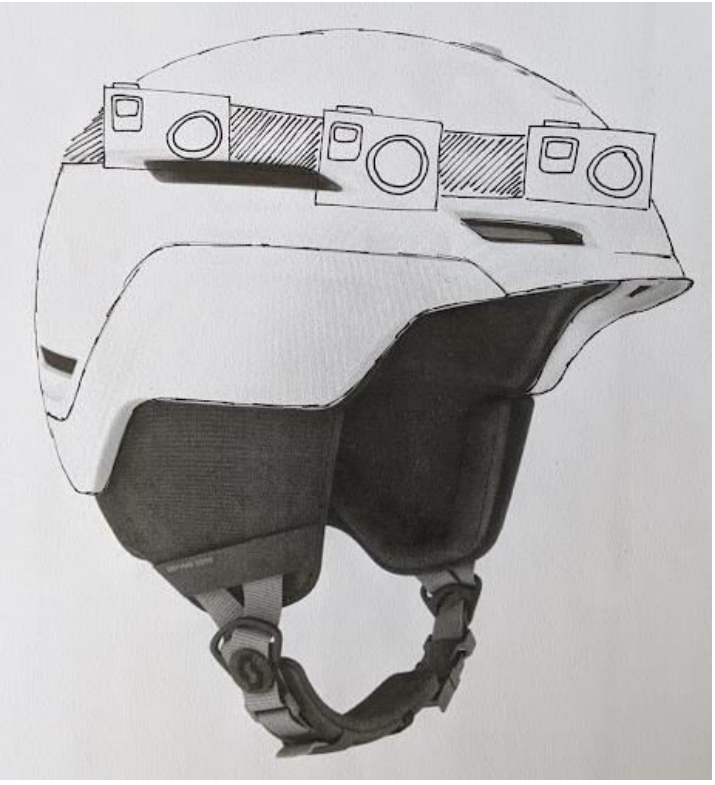


Figure 10 Helcam Hybrid Sketch

"Helcam" is an idea where multiple skiers around the slope would be wearing a helmet with cameras attached and constantly recording. All skiers would be wearing an identifiable band. The footage would then automatically identify skiers based on their band and return an edit of their footage.

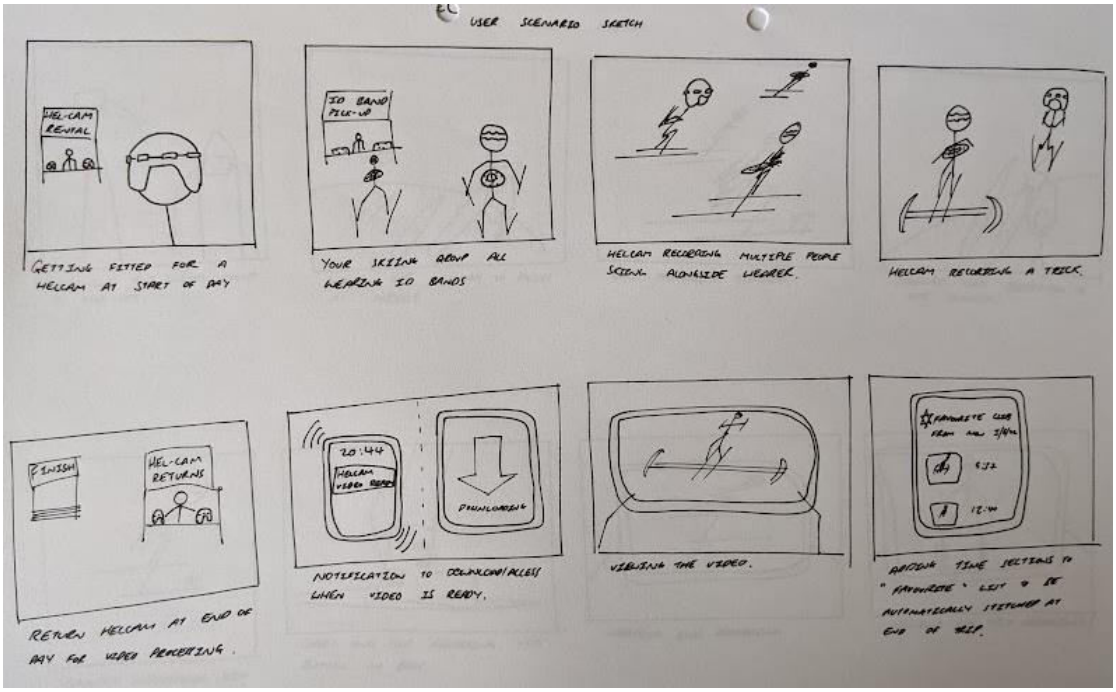


Figure 11 Helcam user scenario sketch

This idea was borne from the need for spontaneous events being captured with the thinking that if these cameras are constantly recording, then they will capture more spontaneous moments. However, skiers would have to be near someone recording which meant that the natural, unpredictably memorable events would not happen and the need to follow a Helcam wearer would disrupt the normal skiing flow.

<u>Swivel Mount</u>

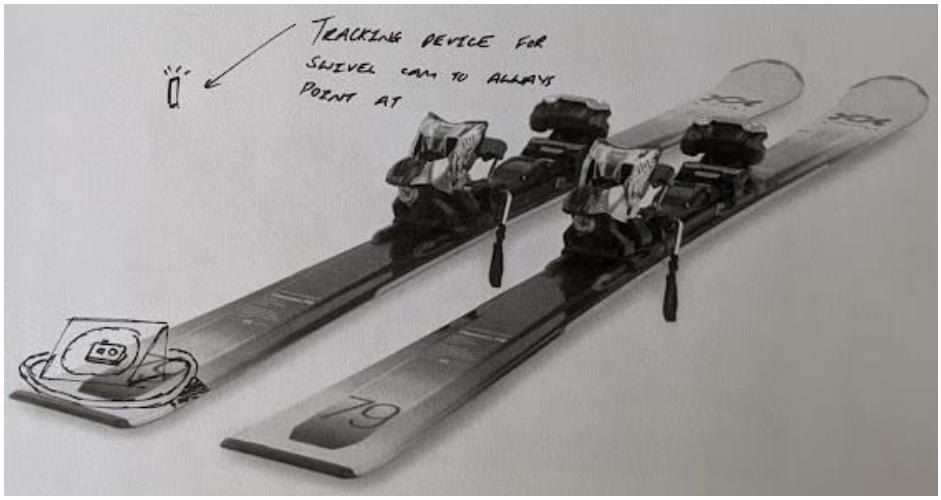


Figure 12 Swivel Mount hybrid sketch

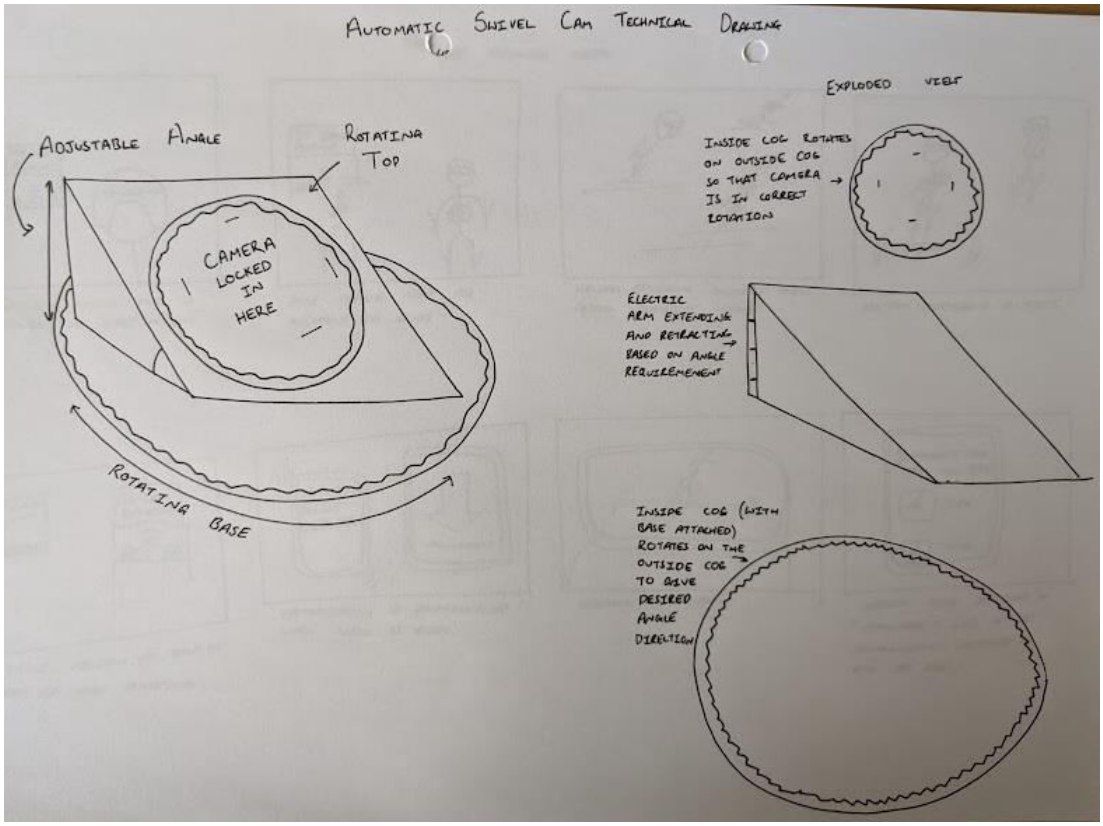


Figure 13 Swivel Mount Mechanical Drawing

"Swivel Mount" is a mount attached to someone's ski which automatically adjusts itself and swivels to be pointing at a tracker device. Swivel Mount meant that the skiers flow would not be disrupted as the skier who needed to be in shot would just hold the tracking device. It is also social, where a group of skiers can ski near the skier with the tracker to all be in shot.

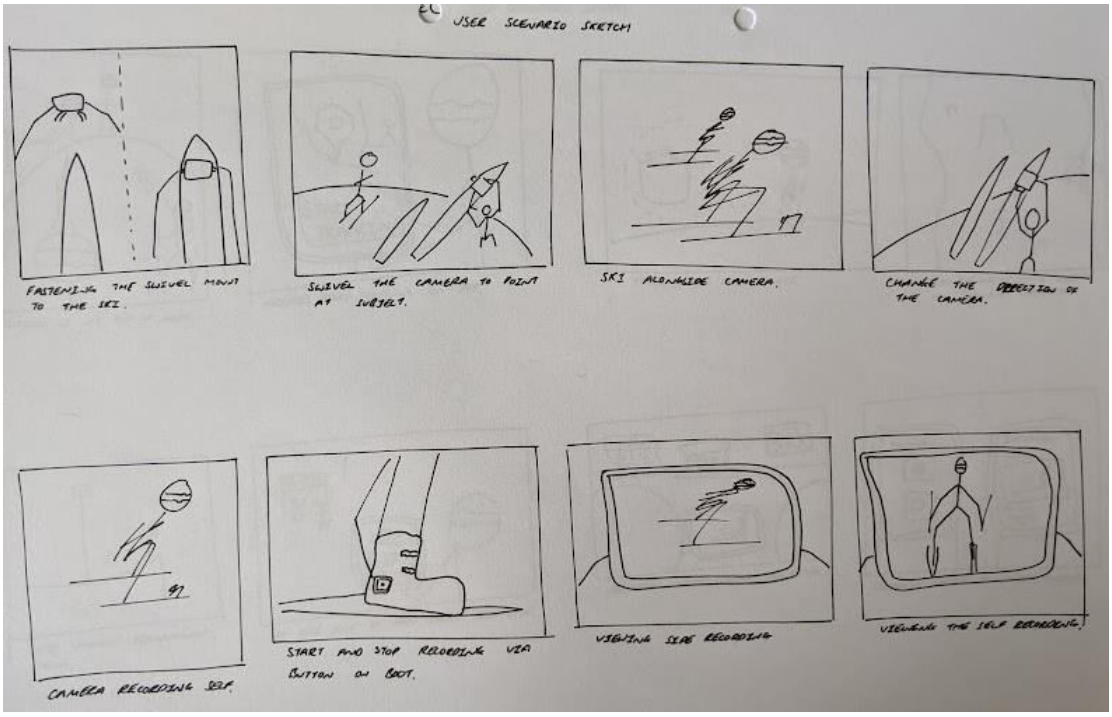


Figure 14 Swivel Mount usage sketch

However, Swivel Mount being one camera with one continuous attachment meant footage quality drawbacks. Firstly, all shots would be low and from a similar angle, making the resulting footage rather dull. Secondly, when used for self-filming, the captured shot would not be able to convey a jump, crash, or speed section very well, which are all key moments which users desire to be captured.

<u>"Borsk" - Ski Area</u>

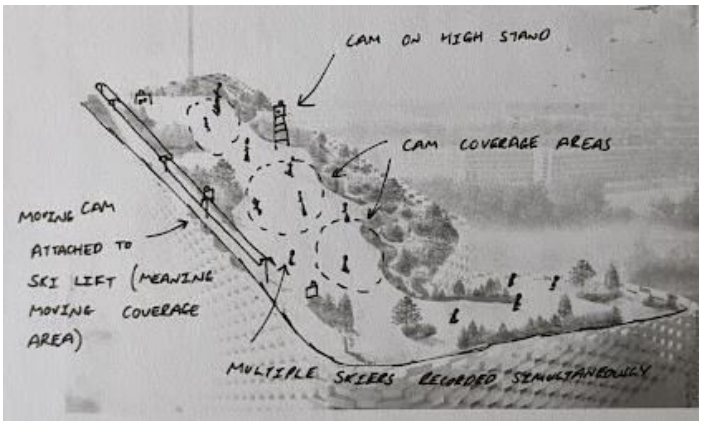


Figure 15 Borsk hybrid sketch

"Ski Area" is a concept where there are multiple cameras dotted around a slope, each constantly recording with coordinates for what is in their field of view. Users will carry a tracking device whilst skiing. At the end of the day, users will submit their tracking data which will be matched against the camera recordings to result in an edited video of their ski. Cameras (and their areas) would be specifically positioned at potentially memorable locations, such as that of a jump, speed section, or crash-prone area.

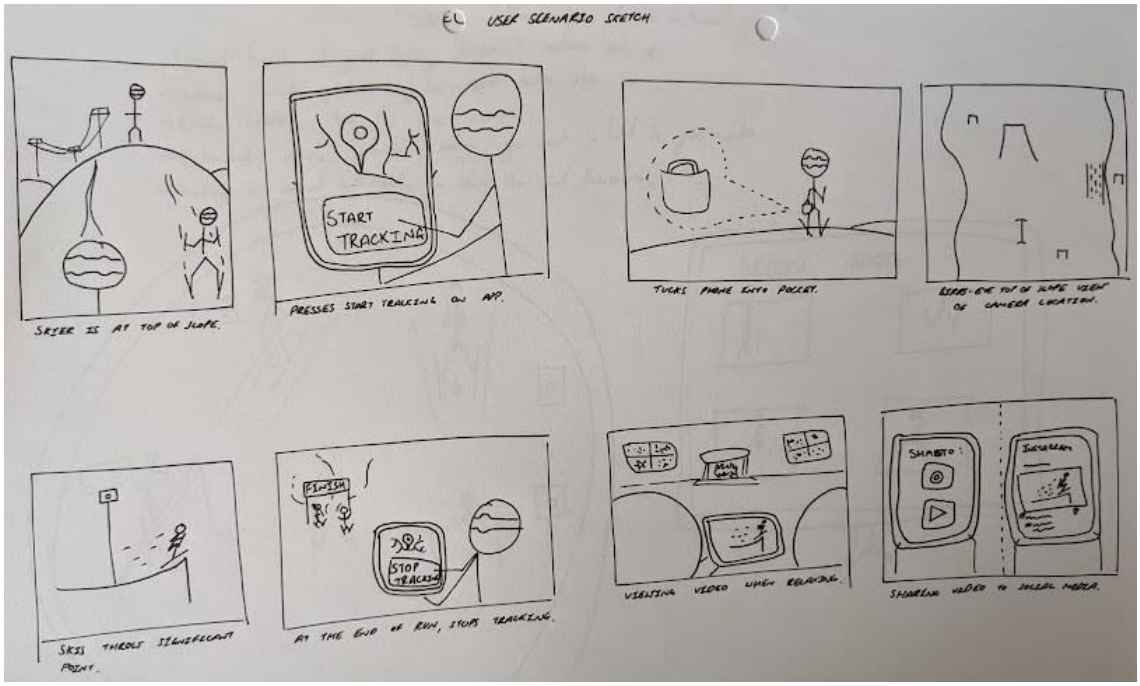


Figure 16 Borsk initial usage sketch

Ski area allows the capture of spontaneous events if there are enough cameras. Also, the required user effort and responsibility is kept to a minimum as all that is required is to start a tracking device.

Ski area was chosen as the idea with which to move forward because it met key design criteria of capturing unpredictable moments, being able to capture a diverse assortment of events, and having minimum user responsibility. The original idea showed no inclination of breaking any of the previously discussed design principles and insights. Moreover, this idea was more practically achievable than Helcam and Swivel Cam. The identifying system for Helcam would be difficult to implement with the quantity of skiers on the slope, and Swivel Mount's footage whilst attached to a ski would be extremely bumpy and practically unwatchable.

5.3 Refining Idea

5.3.1 Interacting with the System

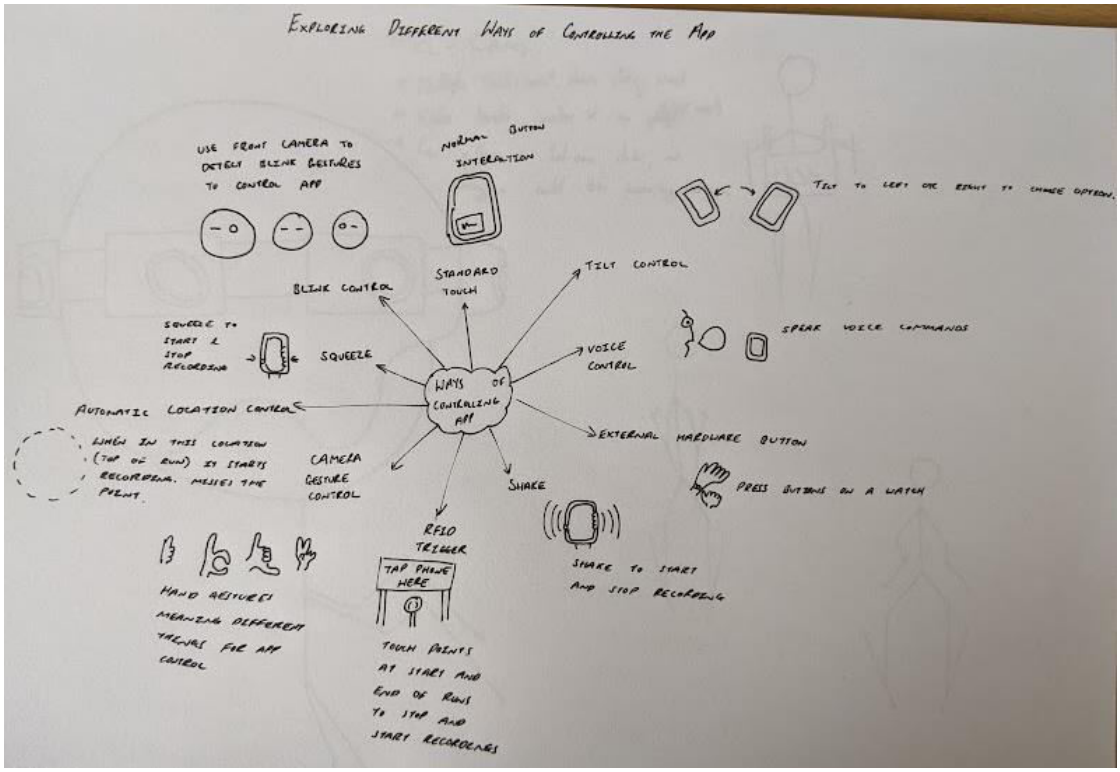


Figure 17 Interaction ideas mind map

System interaction with the ski area design includes interaction points such as learning the system and how to use it, starting and stopping the tracking, and accessing the resultant video. Whilst the original concept envisaged the user holding a custom-made tracking device, it was quickly apparent that this wouldn't be able to provide as much system visibility as a mobile phone app, which would be needed for learnability, and it's limitations would mean it couldn't serve the resulting video which could hamper simplicity and satisfaction [24].

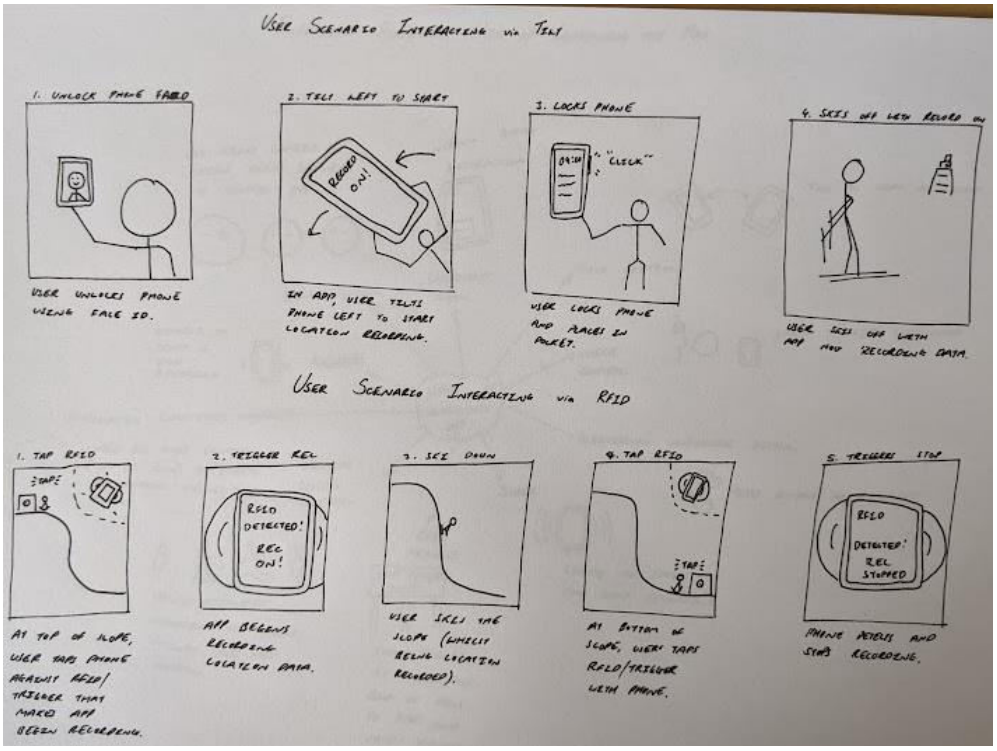


Figure 18 Tilt interaction usage sketch

The key interaction to be designed was how the user starts and stops being tracked, as this is what the user would be doing whilst on the slope which makes it the most vulnerable interaction. The work environment was a key aspect to be conscious of, as a user at the top of the slope (to start tracking) whilst standing on skis meant that any interactions which were too intricate could be difficult to perform. One promising design is a tilt feature, where to start and stop tracking, the user could tilt the phone. This was attractive because it meant the user didn't have to remove their gloves, however it could be easily triggered unintentionally which would disrupt recording. The most reliable interaction was simple application buttons. This is where the user pulls out the app to start tracking at the top of a slope, and at the bottom uses the app to stop tracking. Buttons carried the least risk in implementation, and even though buttons mean the removal of gloves to operate, this is likely to be quicker than if a tilt, or hand gesture interaction, were mis performed.

5.3.2 Editing Options

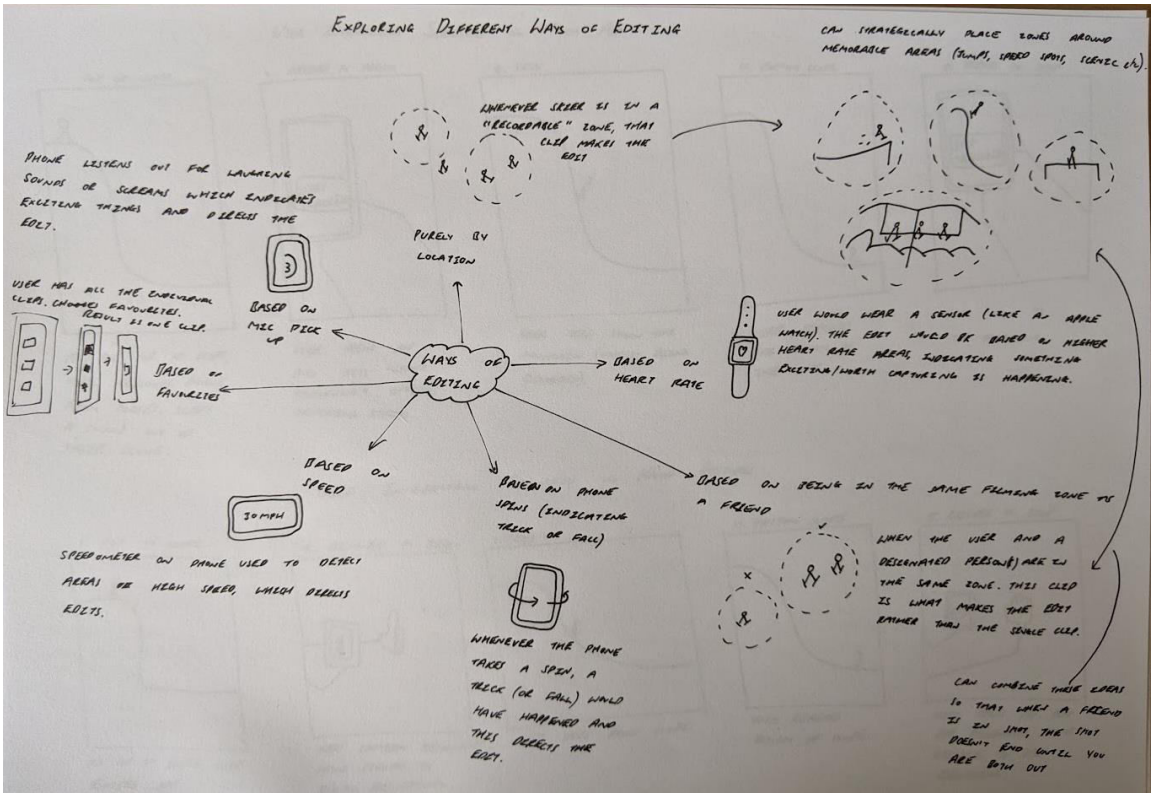


Figure 19 Exploring different ways of editing

The ski area design would generate as many clips as there were cameras that the user passed through. These clips would then need to be edited to serve a final resulting video to the user. There were three threads of designs which were considered. Firstly, a variable based edit design meant that the mobile phone could monitor a variable (speed, user heart rate, altitude changes etc) and then edit the clips based on when that variable notable. A second design was the serve all of the clips individually to the user and allow the user and their friends to vote on which top ten clips should make the final edit. The third idea thread was to serve all the clips together, meaning the resulting edit would be a compilation of every camera the user passed through.

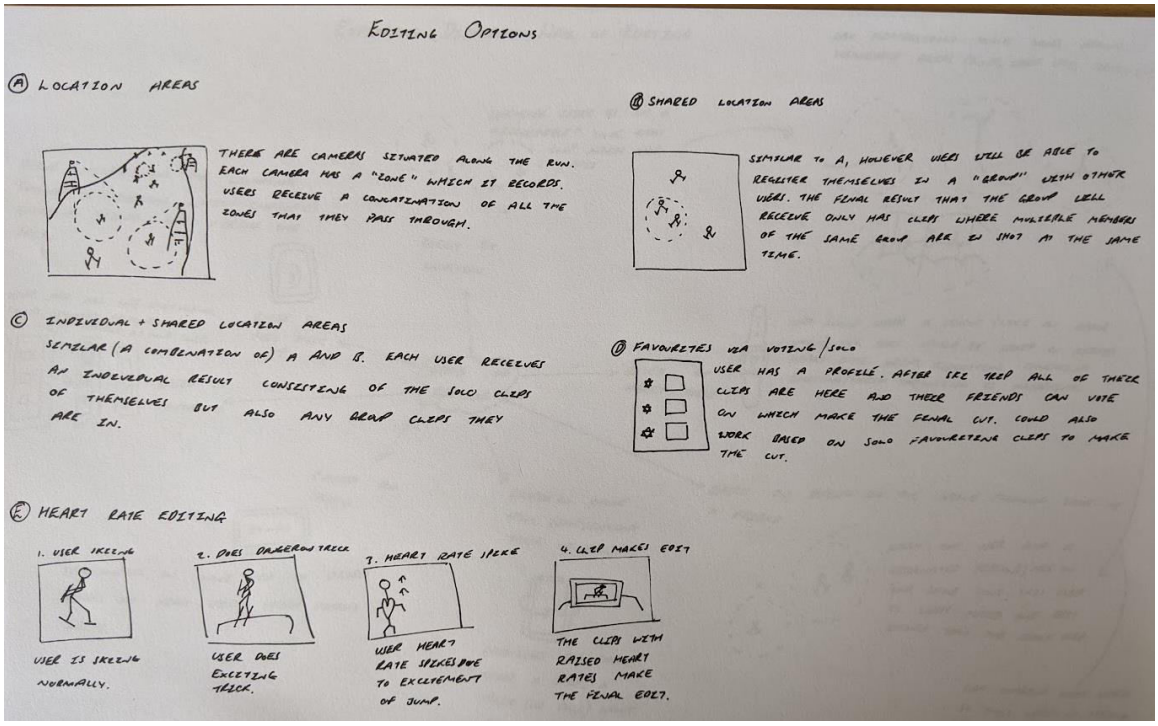


Figure 20 Exploring editing by location area, shared location area, favourite clips, and heart rate-based editing

Whilst variable based editing allowed for a more concise edit, it brings risk of not including all memorable moments because they didn't trigger a variable, violating the design principle that desirable moments are unpredictable. Voting based editing would allow all memorable moments to be picked up and included in the edit, however the voting would create another barrier between the user and the result which is another opportunity for the process to be delayed or disrupted. The cumulation based edit was chosen for its simplicity and absence of need for user intervention. It also meant that all captured moments would be included, therefore users are more likely to receive footage of a memorable moment, despite the edit being less concise.

5.4 App Interface Design

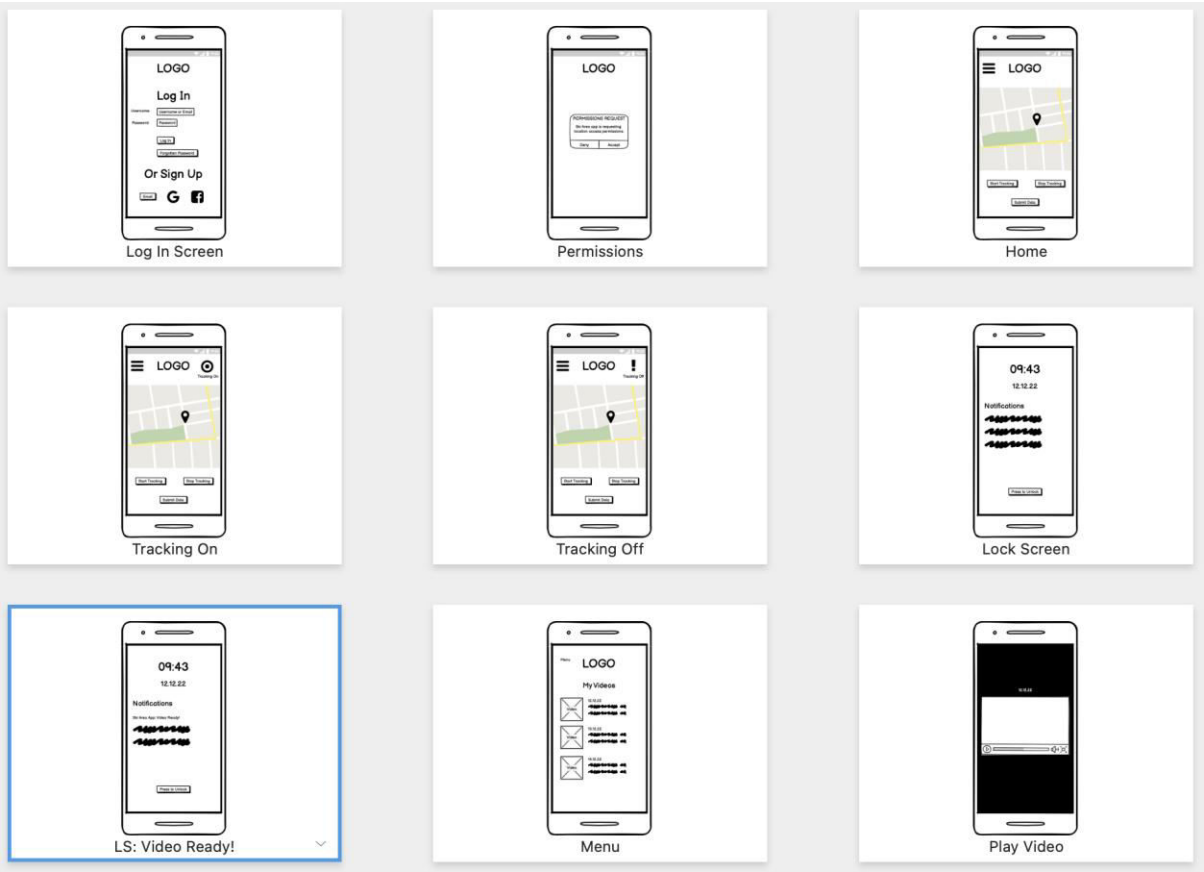
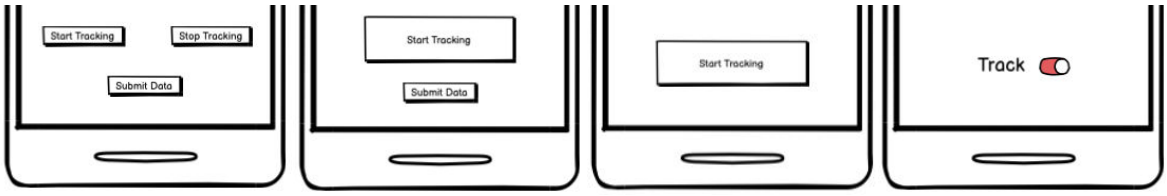


Figure 21 Early wireframe overview

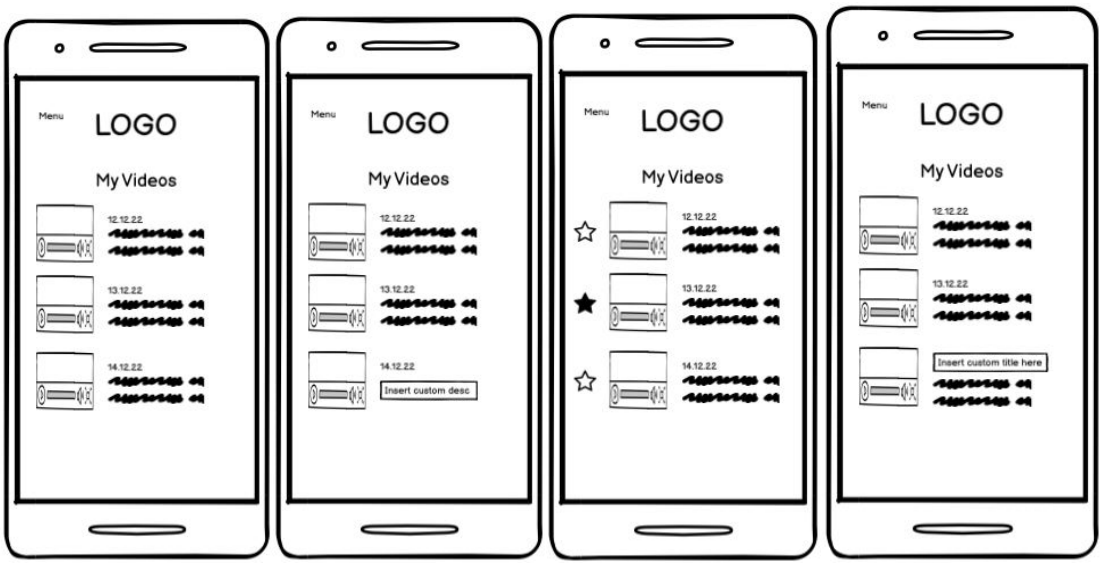
A mobile application with button interaction and cumulation editing was then sketched and wireframed. The application allows a user to login, then the user can use buttons to start and stop location tracking, submit the data to the server, and access and share the resulting video of that day.

To refine the interface design, the process focused on developing from the design principles derived earlier, particularly usability and error prevention, and then system visibility. Once developed, the app wireframe was given a simple aesthetic which allowed easy use of its features.

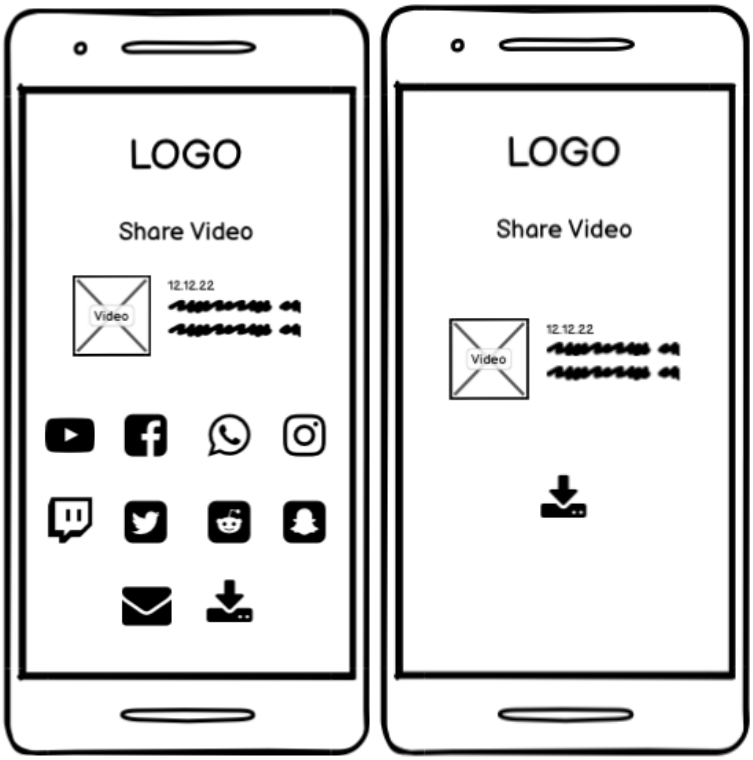
5.4.1 App Usability and Error Prevention



The main error prevention design progression was the development of the tracking buttons. The initial design had buttons which could easily be pressed unintentionally. As the design progressed, buttons were dynamically eliminated so that only what the user needs to see is shown. The later designs discard the “submit data” button as in these versions, the data is automatically submitted at the end of the ski day, which creates one less task for the user to perform.



Another usability development was the application menu, used for navigating between the tracking section and the videos available section. Starting with a hamburger menu style [43], it was found that this was an overcomplicated process for switching between screens, especially for an app which only has two sections. As the tracking buttons developed and required less screen space, there emerged an abundance of white space in which the simpler bottom menu bar could be placed. The bottom menu bar also gives greater visibility as to where the user is within the app system.

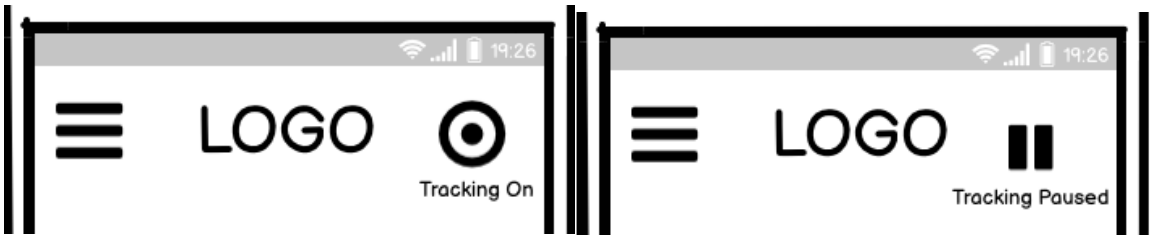


A final usability progression was the development of the sharing screen, used for sharing the resulting video in a way which suits the user. Initially, direct sharing options to platforms were designed into the screen, however this gave an information overload, straying from a usable minimalist design [19]. Options were designed out to simplify the design, however

this restricted where the user could share to, breaking principle that the result should be easily shareable. The last design shows the use of the operating system's native sharing features. Whilst surrendering design control to the OS means that the user will have to use a potentially cluttered option array, the OS design choice means that it is more likely that the user's sharing preference will be catered for and there is familiarity [21] in the layout, both of which would compensate for the cluttered option layout.

5.4.2 System Visibility

In a design which is a complimentary system to the overall skiing, system visibility is essential as it allows quick, easy, and simple interaction and use of the system – which leaves the user more time to ski. The first visibility aspect to be developed was the map view. Having a map view will allow the users to see where they are on the resort. Initially, user location was shown using a round pin, this was useful to show the location, however it was developed to use a directional pointer, which allows the user to orientate themselves on the slope. System visibility on the map view was also increased through the development of including camera positions. Initially no camera locations were shown, then camera locations, and finally only the recording areas. Showing only the recording areas gives the user an indication of exactly where they will be recorded whereas showing the actual camera position means the user must guess roughly where that camera would be recording. By knowing recording locations, the user can use the system as desired as they will know exactly what the system will capture.



Notification of recording status is a key downfall of existing options which this design looks to alleviate. The development progresses from a small icon change within the app, to a larger

indication of recording, as well as a home screen notification of recording, status bar notification of recording, a noise/ vibration to indicate recording, and the stop/ start button having a colour indication of recording. Notifications continue with a home screen alert to indicate when the video is ready to be served. Clear visibility of system status allows the user to have peace of mind in what the system is doing. This allows for a more relaxed and enjoyable user experience.

5.4.3 App Aesthetic

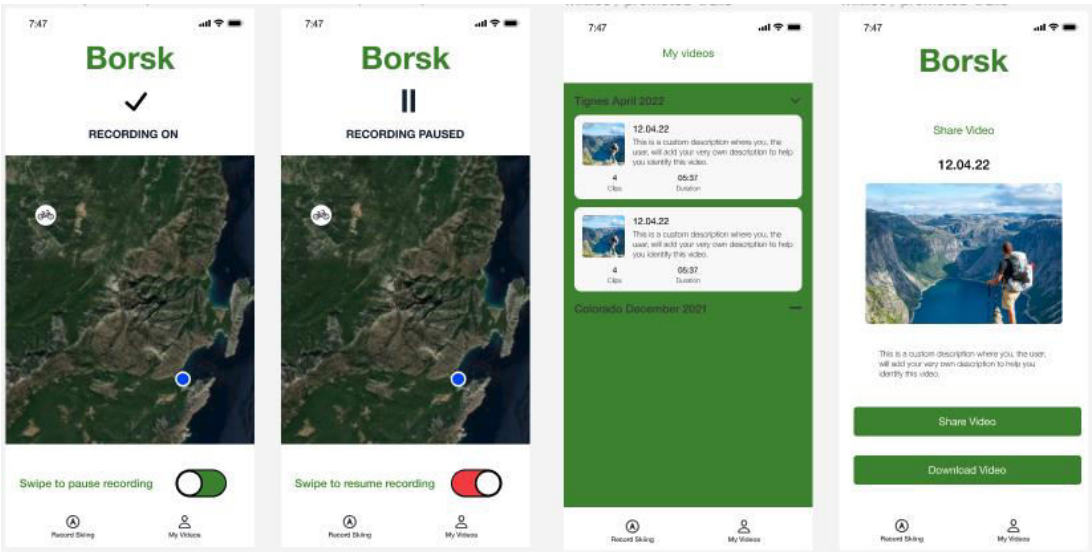


Figure 22 Early app aesthetic design

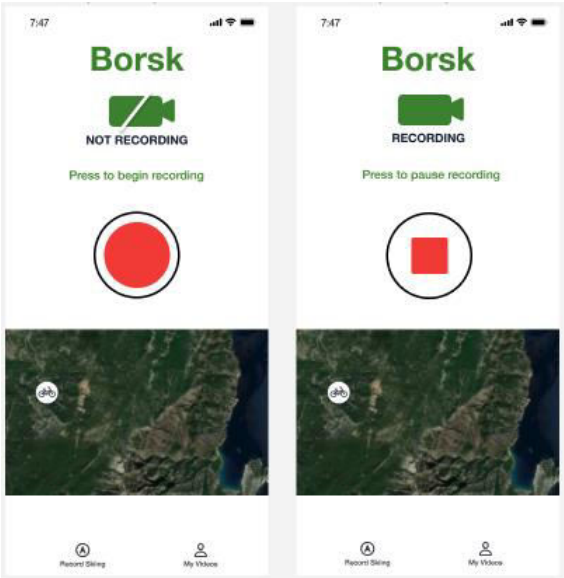


Figure 23 Developments in app aesthetic design

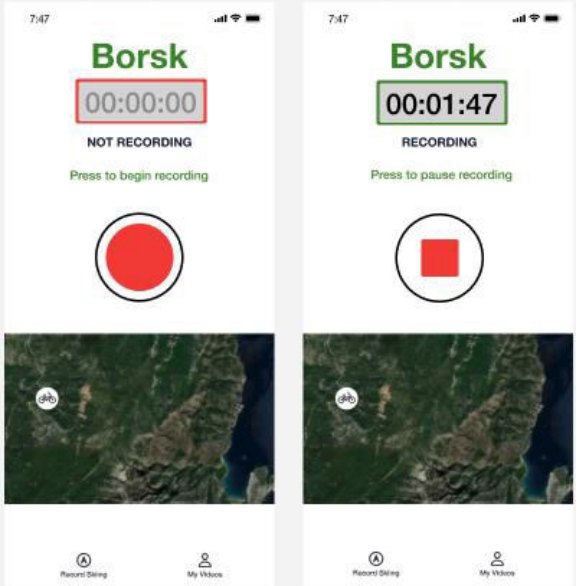


Figure 24 Timer design in app aesthetic

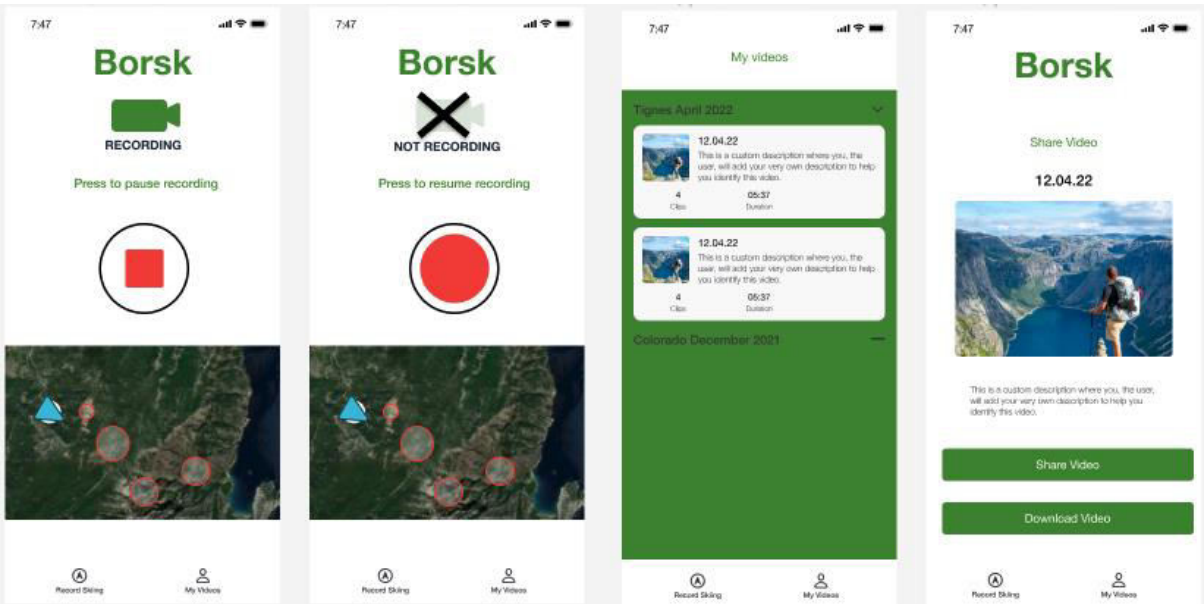


Figure 25 Final app aesthetic design

The design principles of this project allude to a simple app, which can be used quickly and easily to achieve a goal and then exit the app. The app needs to be functional and efficient. Due to this direction, the aesthetic must prioritise ease of use, simplicity, and functionality.

The functionality and usability of this app is designed primarily into the basic layout, the scarcity of buttons, and the presence of notifications. Therefore, as the design objective for the app is functionality, the app aesthetic is designed to be extremely simple to allow the previously designed functionality to remain central to the user's focus, without excessive distraction.

The app uses a contrasting colour scheme (green and white), along with a clear, bold, and consistent font to make information extremely easy to read. Straightforward language such as "Start recording" has been prioritised over unclear words to prevent error and differing font

sizes and bold font versions have been utilized to allow quick understanding of the system status such as “Recording started”.

The aesthetic is consistent, both in theme (colour, font, imagery) and layout. A consistent theme makes it easy for the user to know they are inside the app and contributes to any branding into which the product can be a part of. A consistent layout makes it unchallenging for users to quickly open the app at the top of a slope, begin tracking, and leave the app without causing a significant disruption to the skiing flow.

6. Final Design

Figure 26 Slope model with cameras installed

This chapter will describe the system using a step by step walk through of the complete user experience, accompanied by how the app will look and respond at each interaction. It will then explain how the design attempts to adhere to the design principles (4.2). The full final design can be found in Appendix E – Final Design.

6.1 The User Experience

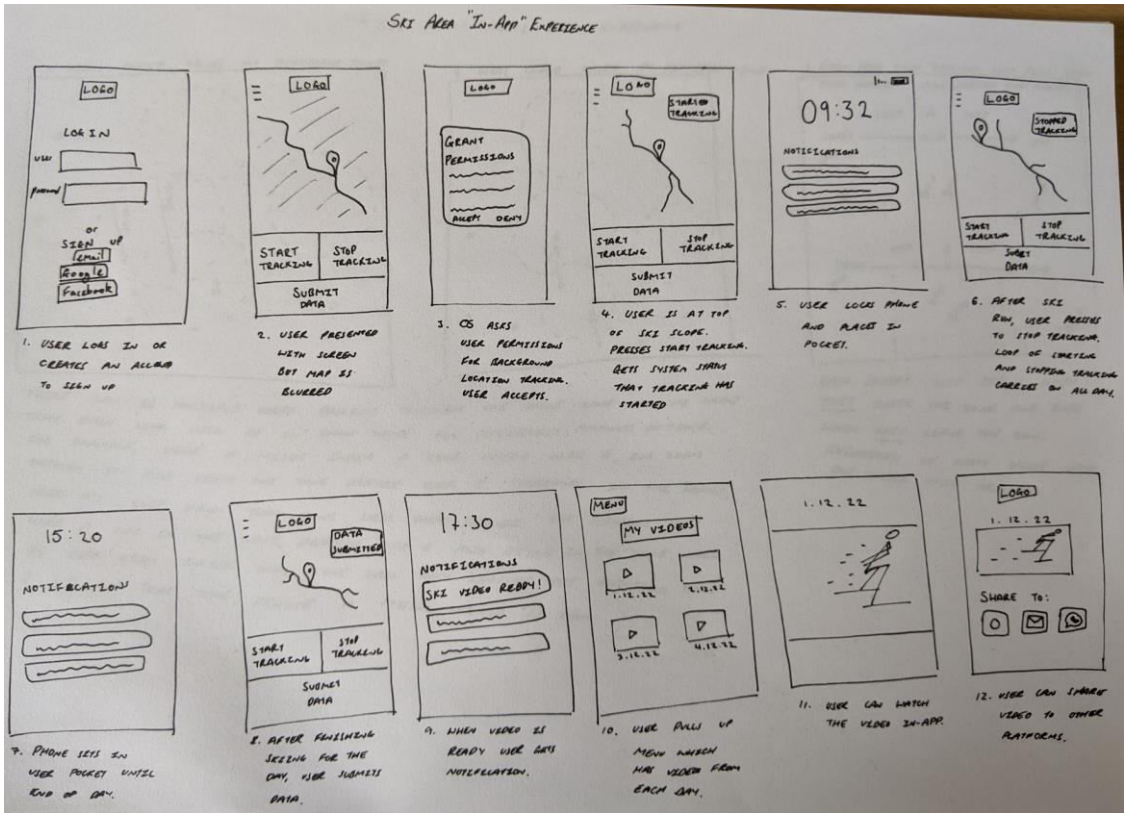


Figure 27 User scenario sketch

1. Before leaving the accommodation, the user will download and sign in to the Borsk app.
2. When at the top of a Borsk-enabled slope, the user pulls out their phone. They can see where the recording zones are. The recording zones are large enough that they don't require the skier to adapt their skiing line.

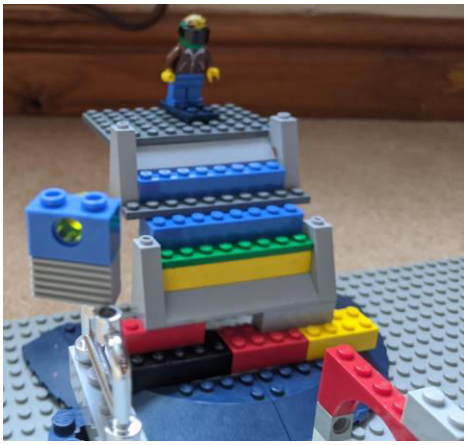


Figure 28 User at top of slope

3. The user presses the button to start recording their location data. They receive confirmation that the phone is recording via feedback within the app, a symbol which appears in the phone menu bar, and a beeping sound.
4. The user locks the phone and can see a recording notification on the lock screen. The user returns the phone to their pocket.

Figure 29 User skiing route through camera scopes

5. The user skis down the slope as they would normally, with spontaneous memories being created and different memorable moments happening. A friend is often skiing near them.
6. At the end of the run the skier unlocks the phone and presses to pause recording. This is confirmed via feedback on the app, change in button colour, the disappearance of the phone menu bar symbol, and a beeping sound.
7. The process of resuming and pausing recording on all Borsk-enabled runs repeats on multiple runs. The user *could* leave recording on; however, they wish to conserve battery usage. At 5pm the ski slopes close.
8. At 6pm the user receives a lock screen notification that their video is ready.
9. The user watches the video using the operating system's native video player. The video is an edit of all the clips that they were in that day, when the friend is skiing near them, the friend is included in the clip.
10. The user selects to share the video to a social media via the OS's sharing options.

6.2 Design Principles

The system matches principle one which is to create a holiday souvenir. Whilst this video can have other uses such as technique analysis and entertainment content, the shot positioning and editing decisions optimises the result for holiday souvenir use.

Shot positioning and editing decisions also support principle two, which states that there must be three recording subjects: the user, the group, and the scenery. This design gives flexibility and control over the subjects which are recorded. Individual recording will happen when the user enters and exits recording zones. To record groups, skiers can ski within a 10m radius of the tracked user, and they will be recorded. Some cameras are angled to focus on scenic shots.

This design allows for significant events (principle three) to be recorded through the strategic placement of the recording zones. By placing recording zones over areas where significant events occur, those events are prioritised. There is a trade-off between prioritising significant events and recording unpredictable, spontaneous moments. Therefore, detailed foresight,

slope analysis planning, and strategically placed cameras are needed to enable the system to primarily record significant events but can also capture spontaneous moments.

User responsibility (principle four) is minimised in three ways. Firstly, the only equipment that the user needs to bring is their mobile phone which adults will already be carrying. Secondly, the data submission and editing system is automatic. Thirdly, the camera angles are already set up, meaning there is no user responsibility to mount, position, or operate a camera. The only user responsibility is the starting and stopping of tracking which is only a design feature due to battery conservation.

Minimising user responsibility also supports principle five: minimize ski flow disruption. The lack of set up means that the only task a user must complete is to start tracking before the run and stop tracking after the run. Then, due to the recording zones, the skier can move through the zones whilst following their normal skiing path. These features minimize the overall disruption by only requiring an app trigger rather than camera mount and eliminate the "in-skiing" disruption as the zones mean no stopping and starting is required to capture the recording.

This design produces high quality recordings (principle six) in two ways. Firstly, as multiple shots are used, each shot can be recording on the most appropriate camera set up. For example, some shots are more suited to a DSLR and others a GoPro. This system incorporates the two. Secondly, these shots are stationary and non-user operated, which means that there is a lower risk of the cameras being damaged and restrictions such as weight, size, and ease of holding do not apply. This allows high-quality cameras to be used and high-quality recordings captured.

The final principle is that the footage is easily shareable outside of the system. The system utilizes the mobile operating system's native sharing capability to be able to share the video directly from the app. This allows a multitude of sharing channels in a format which is familiar to the user.

7. The Prototype

The final stage in the design process is the prototype. A prototype was created for evaluating the usability of the design and validating its technical feasibility. Full build instructions are available in Appendix F – Prototype Build Instructions.

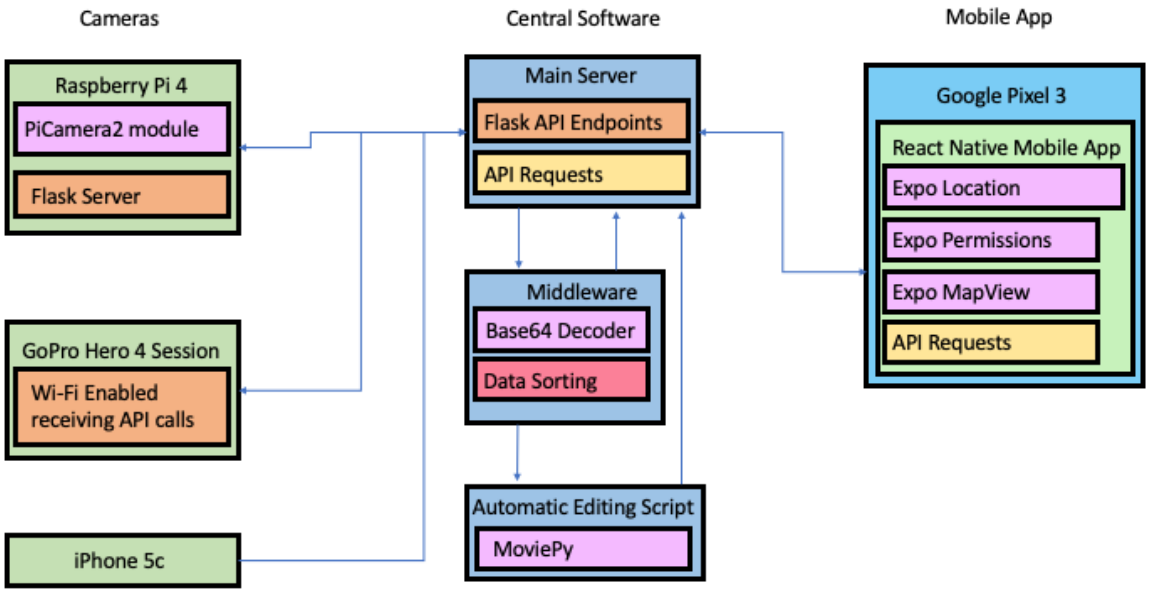


Figure 30 Prototype Environment Overview - Detailed build instructions in Appendix F

7.1 Prototype System

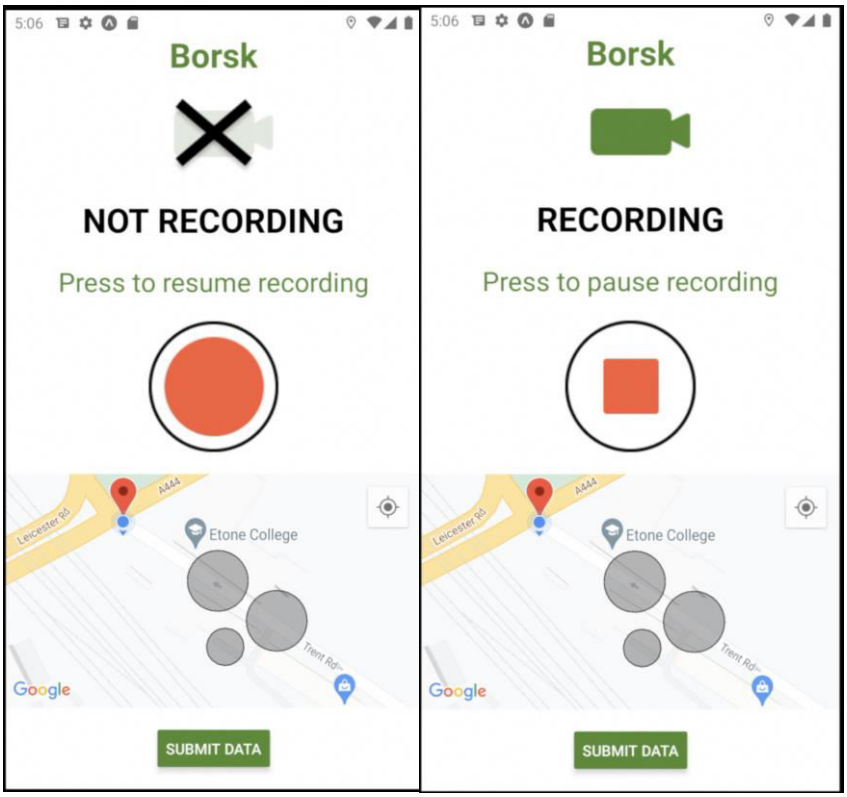


Figure 31 Prototype mobile app before and during recording

Figure 32 Still from prototype camera A

Figure 33 Still from prototype camera B

Figure 34 Still from prototype camera C

The prototype system uses three cameras which are positioned along the slope and have Wi-Fi connectivity, with the Pi running a Flask server. Another Python Flask server is run from a laptop, this is referred to as the "main" server. The main server is used to make API calls to start and stop the cameras, as well as edit, organise, and serve the resulting video. This server is also used to handle API calls from the mobile application with the tracking data.

The mobile application is written in React Native. The application interface has a map view with a pin locator and two buttons for starting and stopping tracking. After the user has tracked a run, the mobile application makes an API call to the main server, passing over the run data for automatic editing. The prototype user interface (UI) has been designed to allow the user experience to flow as expected, in practice the UI would be implemented by a specialist however this project aims to explore the wider user experience, not user interface,

7.2 Technical Implementation Challenges

Building the prototype was a technically complex process as there was four relational programs to build. A server was built on the pi to allow remote recording, a main server was built to manipulate data and trigger cameras, an automatic video editing program was built, and a React Native mobile app was built as a UI and location tracking device. This section gives an overview of some of the significant technical challenges in this build and how they were overcome.

Location tracking was the essential functionality needed in the app. One difficulty was implementing the app permissions needed to allow tracking which was difficult due to the way the app must signal to itself, and the OS, that the correct permissions had been obtained. Eventually the Expo Permissions library was used to handle permissions. A second difficulty was that due to enhanced OS security, asynchronous background location tracking was not feasible to implement. Foreground location tracking through a map view was the only reliable

location tracking implementation, therefore the app design had to incorporate a map view for the app functionality to work.

Working with the Pi caused many technical challenges due to a recently updated camera module which had few online discussion topics existing. Also, the original technical design had the Pi editing the Pi clip locally before sending the edited clip to the main server. In practice, the Pi would freeze when using the MoviePy library needed for editing. Therefore, the entire Pi footage (not just the edited clip) needed to be sent to the main server, slowing down the entire system. When this Pi footage was a large file, it was seen to lose quality when sent to the main server. As a result of this, the usability study neglected to use the Pi, opting for higher quality mobile phone footage.

The main server also had the capability to remotely control the GoPro. However, it was later discovered that this functionality required a dedicated Wi-Fi receiver. The main server also needed a Wi-Fi receiver to communicate with the Pi and receive API requests to be controlled. My laptop only has one Wi-Fi receiver, therefore the GoPro had to be manually controlled.

8. Usability Study

A usability study was conducted to evaluate the design of the ski recording system. The study aimed to collect usability data in the form of qualitative quotes and Likert based ratings. The usability study and design principles justification (6.2) form the basis for evaluating how user-friendly the design is.

8.1 Study Design

The study was conducted under the ethics application "Designing a User-Friendly Ski Film System" which can be found in Appendix A – Ethics Form. The study took the form of a 40-minute session broken into two parts. Firstly, participants used the mobile app to record location whilst running a route which had three cameras placed along it before they were shown the resulting footage. In part two participants answered a series of open, Likert, and scale questions whilst discussing their opinions. Five participants took part, and the questionnaire can be found in Appendix G – Usability Study Questions.

The questionnaire aim was to begin with general opinions about the design before discussing specific aspects which were prominent themes in the design process such as ease of use, system visibility, cinematography, etc. Finally, the questionnaire used a NASA Task Load Index [44] to gain further insight into the subjective workload regarding the design.

8.2 Findings

8.2.1 Overall Impression

Participants quickly grasped that the system was novel and felt it would positively impact their skiing experience. When describing the system, participants recognised the use of location tracking and multiple cameras in the recording process as they used "location-tracking combined with cameras" in their system descriptions. The unusualness of this system was most apparent when participants compared it to GoPro. There were three key comparisons made. Firstly, participants recognised the difference in set-up demands from each system, describing the GoPro as "needing lots of little things to be right" for it to work whereas this system as one which you "don't have to remember anything". The second key comparison was the recording quality. Participants described this system as one which produced "steadier" and more "contextual" footage than the GoPro. The final comparison was the difference in ease of use between the two systems, as participants described the GoPro as "constant fiddling" and "hassle", compared to Borsk as "easier", "simpler", and "more straight-forward".

Participants were "excited" at being able to use the system, were "eager to see the outcome" and felt "motivated" to focus on the skiing. All participants agreed that Borsk would "make the skiing experience more enjoyable", and that they would use the system if it were implemented. Furthermore, participants felt "normal" and "relaxed' whilst using the system, showing that Borsk alleviates mental demand, allowing participants to purely focus on the activity rather than the act of recording. The lack of work allowed them to feel "at ease" and remain feeling "stable". Consequently, Borsk was shown to be a design which falls into the background, allowing the user to focus on their primary objective whilst simultaneously achieving the secondary objective of capturing skiing footage.

8.2.2 Skiing Disruption

Minimising disruption to skiing was a key design principle. Standard recording processes require disruption through camera setup and the recording process, however Borsk aimed to minimise this disruption to allow users to purely focus on the skiing. 100% of participants somewhat disagreed or strongly disagreed that Borsk would be disruptive to the skiing experience and that Borsk is a less disruptive experience than using a GoPro. Not only did participants state that "using apps whilst skiing is normal" for themselves, but they also explained that they "open a lot of apps on the slope anyway" such as Spotify and metric tracking applications, therefore they felt that one more app to manage was "no hassle". Furthermore, participants described how they "open and close apps all day" and this is a "very familiar way of doing things" meaning it's workload demand would be minimal. One participant described how "faster unlock methods" such as finger ID, face unlocking, and eye-scanning makes entering and exiting apps a seamless experience. These quotes, backed up by Likert data, show that Borsk causes minimal disruption to the skiing experience, which allows the user to focus on enjoying the skiing.

8.2.3 App Simplicity

Minimal disruption is one derivation of app simplicity. Ensuring a simple app was a conscious design choice, executed through a basic layout, clean aesthetic, readable font, and visible system status. 100% of participants felt that the app was simple to use and found it easy to know which buttons to press and when. Participants described the layout and aesthetic as the "opposite of intimidating", being "clear" and "obvious" what to do and when. Participants liked how the app "only had one screen" and described the work requirements as "*only* one click" and "*just* pressing a button". Likert data shows that all participants were easily able to learn the system and consistently able to recognize the state of the system, with quotes stating that the "app shows clear response to actions", with an appreciation for the clarity of the words "recording" and not recording, as well as a "attention grabbing" big red button, and "obvious" camera recording icon. A basic app and obnoxious system visibility lead participants to describe it as "simple", "fast" and "very quick to execute" actions with. These quotes show that the app design achieved the principle of simplicity and system visibility, permitting the prior goal of minimising disruption to skiing.

8.2.4 Map View Visibility

Map view was designed as a simple way to allow users to locate where they are on the slope and where the recording zones are in relation to themselves. This would allow them to prepare for, and occasionally "perform" for, the cameras. Whilst some users found the map view "kind of useful" as it would let them know "where I might want to do something special", overall, all participants were neutral about the feature improving the experience. Multiple participants explained that they couldn't "remember where the recording zones were" and that despite the location data being nice to know, it "wouldn't impact my skiing behaviour". Whilst avoiding impacting skiing behaviour is desired as it aligns with minimising skiing disruption, the overwhelming response to the feature was neutral and indifferent. Therefore, the success of this feature as a guide to displaying recording zones and user's location to them was successful, yet rather useless.

8.2.5 Work Demand

The design process presented the challenging balance of requiring a lot of user work in return for more control over the final video versus requiring little user work in return for less control over the final video. Borsk opted for the latter, giving users virtually no control over camera positions or editing, in return for a completely automated experience. The average perceived physical demand was 0.6% and the average effort required was 3.6% whereas participants rated themselves as 97% successful in accomplishing the task of using the system. Participant work demand was reduced through the physical aspect of bringing, setting up, and operating camera equipment as well as the mental demands of transferring and editing footage. Participants appreciated this direction, with many stating that they "don't want to do any work" because of "laziness" and "not wanting to do work whilst on holiday". Participants felt that the work to reward balance was favourable, as 100% of participants felt like having to operate the app was worth the ease of recording. Furthermore, participants enjoyed "the convenience of a finished product" and "not having to do anything" to receive the resulting video. Regarding the entire process, participants showed enthusiasm for having "everything done for you", not having to hold a camera, and not having to "remember to bring anything" unlike the GoPro, which requires the user to bring multiple components. Overall, it is evident that participants strongly prefer a low or no workload, and the Borsk design can accommodate this.

8.2.6 Recording

Ensuring a design which permits desirable footage is critical, as without it the system is redundant. Desirable footage can be obtained through the content and the quality of that footage. Participants described the content that Borsk could capture as "every skiing aspect I would want" and that the design would "capture great moments". Participants thought that Borsk would "capture memories better than any alternative" which further attests that in full implementation, the Borsk design has the capacity to capture desirable content.

Participant opinions regarding the quality of the outputting footage were often based on a comparison with GoPro output. Most participants explicitly appreciated the still camera and the "steady" shots of Borsk compared to the "shaky" alternative. Participants also showed enthusiasm for the multitude of camera angles possible with the system as they liked the thought of having footage of themselves rather than only point of view footage. One participant explained that if the camera placement is right then Borsk would record every shot they would want, meaning system success would depend on implementation as well as the design. 100% of participants could see value in recording through this system. Altogether, participants strongly conveyed that Borsk had the capability to capture memorable content through a high-quality medium.

8.2.7 Foreseeable Uses

The output skiing video has the potential for multiple uses such as social media sharing, further editing, technique analysis, as well as unanticipated uses such as resort advertisement. To cater for an assortment of uses and remain a simple system, Borsk incorporated the operating system's internal sharing mechanism as the gateway to passing on footage to the final location. All participants had used and were familiar with the internal sharing mechanism. All participants also strongly agreed that the internal sharing mechanism would cater to any uses they would need for the footage. Participants expressed that this familiarity

would make the process easy and natural, keeping the design easy to use whilst remaining highly functional.

8.3 Summary

This chapter outlined the usability study conducted to evaluate the prototype and the key feedback points from that study. Participants gained a positive overall impression of the system, seeing value in the novel idea and showing desire to use an implemented Borsk system over traditional recording systems. Participants found Borsk to minimize disruption of the skiing experience through its simple interface and low demand for engagement. The simple interface was seen as easy to use, fast to learn, and suitable for use, with system visibility through imagery and text being easily recognised and understood by participants. Participants showed neutrality towards a map view feature, stating that despite it being "nice to have", it's place in the user's pocket quickly made it redundant as user's wouldn't remember the map view content. Participants appreciated the low work demand of the system. Low physical operation demand meant participants were not required to bring, setup, or operate any equipment whilst low mental demand meant that participants weren't required to manipulate footage. The lack of work demand contributed to increased ease of use and relaxed sentiment. Participants envisaged the system capturing high quality and desirable content when implemented on a slope. They felt that the system would capture every aspect of skiing that they would want to capture whilst doing so through watchable, high-quality recording capabilities. Participants felt that the app would cater for any further uses they would have for the footage, and that the internal sharing mechanism was an encapsulated option for further sharing. Overall, the Borsk prototype has shown it adds value to user's skiing experiences. It has shown that it can functionally perform to a high quality with minimal user work required, but also to be easy to use, simplistic, and visible where user work is necessary.

9. Conclusion

9.1 Project Summary and Outcomes

Overall, the project objectives set out in Section 1.2 have been largely accomplished.

1. A thorough review of literature and existing work has been conducted. This led to the identification of key reasons supporting the importance of this project, primarily memory capture, but also technique analysis, social media content, and advertisement. State of the art solutions in automatic video recording and editing were evaluated to allow for consideration of their applicability to this project.

2. An early user study was conducted to evaluate target user's opinions on existing film solutions and sentiment around recording systems. This study resulted in a list of user requirements (Section 4.2).

3. Data from the early user study as well as heuristic and literature research were modelled, resulting in a list of design principles. These design principles formed the foundation for a design process which began with broad ideation, and pursued multiple iterations and directions, to filter out potential solutions and refine potential solutions until a design which adhered to the principles and user requirements was created. Key features of the design were prioritised for production before a working prototype using a location tracking mobile app and multiple internet connected cameras was created.

4. The design was evaluated through a usability study, using the prototype to allow participants to experience the system and provide educated insights. Study data was then analysed to evaluate the success of the project in designing a user-friendly ski film system.

5. The project created a comprehensive set of design resources to be used in the future development of this work. Resources include literature research, heuristic research, various data models and early user insights, design artefacts such as mind maps, user scenario sketches and Figma sketches, a working prototype with build instructions and an evaluation study of this prototype.

The resulting design has proven to be a user-friendly ski film system. The overall design is ubiquitous in the skiing environment, sparing the need for users to remember to bring, set up, or operate equipment. The application uses bold, concise imagery and lettering to show an easily visible system status. The application also uses generous white space and button size, to allow for a layout and button design which uses familiarity to naturally guide users in app operation. The ubiquitous layout and positioning of cameras ensure that all memorable moments will be captured for the user, and the in-app automatic editing transforms those memorable moments into one easy to digest video clip with minimal user work required. The internal sharing mechanism utilised within the app then ensures that this clip can easily reach its final intended destination, however varied those destinations may be.

9.2 Overall Success

This project attempts to solve the overall problem of capturing skiing moments which are difficult to capture, with the use of this footage primarily being souvenir use but also technique analysis, creator content, and documentation purposes. The project has largely solved this problem as the design allows for enough cameras and specific cameras to never miss a memorable moment, the cameras can always be setup and working correctly to minimise user work, and the result is automatically served, minimising the opportunity for the process to falter.

As a souvenir this project shows great potential as the usability study has confirmed that this is a product users can use easily and want to use. Users have shown that they want to have this footage and have a multitude of uses for it. The resulting system is already a usable final product from the user perspective, which the study has confirmed. Naturally this translates to commercial applicability which shows that the project satisfies a demand in a lucrative skiing market. Whilst promising, before being "ready for market" there are still questions to be further explored in this design which are mentioned in the following section.

The enthusiasm received for this project is a testament to the importance of the previously mentioned human memory capture. Users easily recognize its value and have naturally commented on the uses this system would have (souvenir, technique analysis, promotion, safety). The ease at which users link this system and it's intended uses demonstrates that the project has greatly succeeded in taking the abstract idea of capturing memorable skiing memories to a tangible, user-friendly system.

9.3 Limitations and Future Work

Realistic Environment Conditions

Environment conditions are a key theme of a ski film system design. The app should be workable and visible despite a different landscape, the cameras are positioned at peculiar and unique angles, and the user is in a completely unique headspace as they balance enjoyment and fun with the adrenaline and danger associated with the activity. Whilst the design attempts to incorporate these factors, being unable to implement the prototype in a skiing location has been a limitation in the technical feasibility of the project and of the usability study. There are breath-taking views, exciting moments, and challenging conditions present on a snow-covered mountain which are not present on a street in the U.K. Therefore, the ability to test the product in the desired environment has been a limitation of this study which must be overcome in future projects before implementation.

Equipment Access

Restricted access to equipment has been a second limitation of this study. As a university project with limited resources, this project has utilised the cameras owned by the university as well as personal cameras and phones for location tracking. Whilst grateful for these resources, an optimal implementation of this design would include a range of extremely high-quality cameras which are able to showcase the best recordings possible. Furthermore, limitations in tracking equipment meant a phone was the most feasible option for this study, whilst other options may have been more suitable or user-friendly. Overall, a lack of resources and budget meant that the prototype could not be implemented in its full capacity, thus only providing a snippet of the capabilities of a fully optimised system. Future work could upgrade on the framework built in this project to create the fully optimised system.

Time

Time has been the final limitation in this study. Design processes require iteration cycles where designs are developed, tested with users, and then developed further. This project duration was three months, making it only feasible for one design cycle. Future work would repeat this cycle multiple times to fully refine the design. Time also restricted the design directions that could be explored. More time would allow the exploration of a “group mode”, and different editing options for users. The app interface could be further developed, experimenting with the suggestion of flashing iconography to depict system status, alternate map view iterations, and different editing options for users. Finally, extended time would allow an enhanced usability study which investigates two important aspects. Firstly, the level of instruction required for user success could be explored to assess the intuitiveness of the system. Secondly, time may allow for a usability study timeslot where multiple users can attend and experience the system synonymously, demonstrating its full capability as a multi-user system which is a key design advance on similar works.

A. Appendix A – Ethics Form

University of St Andrews | FOUNDED 1413

School of Computer Science Ethics Committee

22 July 2022

Dear Michael,

Thank you for submitting your ethical application which was considered at the School Ethics Committee.

The School of Computer Science Ethics Committee, acting on behalf of the University Teaching and Research Ethics Committee (UTREC), has approved this application:

Approval Code:	CS16432	**Approved on:**	22.07.22	**Approval Expiry:**	22.07.27
Researcher(s):	Michael Clark				
Supervisor(s):	Kenneth Boyd				

The following supporting documents are also acknowledged and approved:

1. Application Form
2. Participant Advert
3. Participant Information
4. Participant Debrief
5. Consent Form
6. Interview Questions
7. Survey Questions

Approval is awarded for 5 years, see the approval expiry data above.

If your project has not commenced within 2 years of approval, you must submit a new and updated ethical application to your School Ethics Committee.

If you are unable to complete your research by the approval expiry date you must request an extension to the approval period. You can write to your School Ethics Committee who may grant a discretionary extension of up to 6 months. For longer extensions, or for any other changes, you must submit an ethical amendment application.

You must report any serious adverse events, or significant changes not covered by this approval, related to this study immediately to the School Ethics Committee.

Approval is given on the following conditions:

- that you conduct your research in line with:
  - the details provided in your ethical application
  - the University's Principles of Good Research Conduct
  - the conditions of any funding associated with your work
- that you obtain all applicable additional documents (see the 'additional documents' webpage for guidance) before research commences.

You should retain this approval letter with your study paperwork.

Yours sincerely,

School of Computer Science Ethics Committee
Dr Juan Ye/Convenor, Jack Cole Building, North Haugh, St Andrews, Fife, KY16 9SX
Telephone: 01334 463252 Email: ethics-cs@st-andrews.ac.uk
The University of St Andrews is a charity registered in Scotland: No SC013532

B. Appendix B – Early User Study

Qualtrics Questionnaire

Opening Statement

You are being invited to participate in a research study titled "Designing a User-Friendly Ski Film System. This study is being done by Michael Clark from the School of Computer Science at the University of St Andrews.

The aim of this project is to design a system which will record skiers as they ski down a mountain. By participating in this questionnaire you will be asked to answers questions which are designed to allow us to derive insights that will guide our design process. This questionnaire should take 20 minutes.

If you are interested in taking part, please download a copy of the participant information sheet here (email mac37@st-andrews.ac.uk) and retain this for your records before starting the questionnaire. If you have any questions, please email at mac37@st-andrews.ac.uk. Your participation is entirely voluntary, and you can withdraw at any time. You are free to omit any question.

General Skiing Experience

Please describe your day at a ski resort and the moments you'd like to highlight.

How do you feel before a ski trip?

How do you feel whilst skiing and on a ski trip?

How do you feel when you reflect on your skiing memories?

Design specifics

What use would you have for skiing footage? Tick all that apply.

- ○ Analyse and improve technique.
- ○ A holiday memento.
- ○ Share it directly to long form video social media (Youtube, Vimeo).
- ○ Share it directly to short form video social media (Tiktok, Snapchat, Instagram).
- ○ Edit it into my own video.
- ○ Other or none (please specify below)

If you answered "Other" to the previous question, please specify what other use you might have for skiing footage.

Which elements (if any) of your skiing would you like to have footage of? Tick all that apply.

I would like to have footage of...

- ○ My specific technique.
- ○ Scenic shots of the slope and surroundings.
- ○ My skiing highlights.
- ○ All, or as much as possible, of my skiing.
- ○ My activity around the slope outside of skiing (eating with friends, walking around, using lifts etc).
- ○ Just myself as a holiday souvenir.
- ○ Myself and my group as a holiday souvenir.
- ○ Evidence against unsafe skiers.
- ○ Nothing - I wouldn't want footage of any skiing activity.
- ○ Other (please specify below)

If you answered "Other" to the previous question, please specify which other elements of your skiing you would want captured.

In what form would you like to receive skiing footage? Tick all that apply.

- ◯ Raw footage that I can edit myself.
- ◯ Pre-edited short form (1 - 3 minutes).
- ◯ Pre-edited medium form (5 - 10 minutes).
- ◯ Pre-edited long form (10 - 20 minutes).
- ◯ Other (please specify below).

If you answered "Other" to the previous question, please specify the form which you would prefer to receive footage in.

Rate how important each of the following aspects are to you in regards to a ski film system

	Extremely unimportant	Unimportant	Indifferent	Important
Freedom of choice over shot angles	◯	◯	◯	◯
Instantaneous access to footage	◯	◯	◯	◯
Freedom to edit video	◯	◯	◯	◯
Having custom shot angles that no one else has	◯	◯	◯	◯
Group recording	◯	◯	◯	◯
Ability to directly share video to social media	◯	◯	◯	◯
Control over what is and isn't included in the resulting edit	◯	◯	◯	◯
Off piste recording	◯	◯	◯	◯
Jump and tricks recording	◯	◯	◯	◯
Touring recording	◯	◯	◯	◯
The footage being personal	◯	◯	◯	◯

Existing Solution Selection

Which of the following have you used to capture skiing footage? Tick all that apply.

- ◯ GoPro
- ◯ Mobile Phone
- ◯ SkiLine SkiMovie
- ◯ Other

GoPro Questions

Please answer how much you agree with each statement, in regards to the GoPro.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
All of the memories I wanted to be captured were captured	○	○	○	○	○
I felt happy with the resulting footage	○	○	○	○	○
Setting it up was easy	○	○	○	○	○
Recording with it was easy	○	○	○	○	○
I felt happy whilst using it	○	○	○	○	○

Mobile Phone Questions

Please answer how much you agree with each statement, in regards to the Mobile Phone.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
All of the memories I wanted to be captured were captured	○	○	○	○	○
I felt happy with the resulting footage	○	○	○	○	○
Setting it up was easy	○	○	○	○	○
Recording with it was easy	○	○	○	○	○
I felt happy whilst using it	○	○	○	○	○

SkiLine SkiMovie Questions

Please answer how much you agree with each statement, in regards to the SkiLine SkiMovie.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
All of the memories I wanted to be captured were captured	○	○	○	○	○
I felt happy with the resulting footage	○	○	○	○	○
Setting it up was easy	○	○	○	○	○
Recording with it was easy	○	○	○	○	○

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I felt happy whilst using it	○	○	○	○	○

Other Questions

Please answer how much you agree with each statement, in regards to the SkiLine SkiMovie.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
All of the memories I wanted to be captured were captured	○	○	○	○	○
I felt happy with the resulting footage	○	○	○	○	○
Setting it up was easy	○	○	○	○	○
Recording with it was easy	○	○	○	○	○
I felt happy whilst using it	○	○	○	○	○

Closing comments

If you would like to add anything in regards to the study, please do so here.

Closing Statement

By clicking the 'Submit' button below, you are consenting to participate in this study, as it is described in the participant information sheet, which you can download here (email mac37@st-andrews.ac.uk). If you did not yet download and keep a copy of this document for your records, we recommend you do that now.

Survey Powered By Qualtrics

Semi-Structured Interview Questions

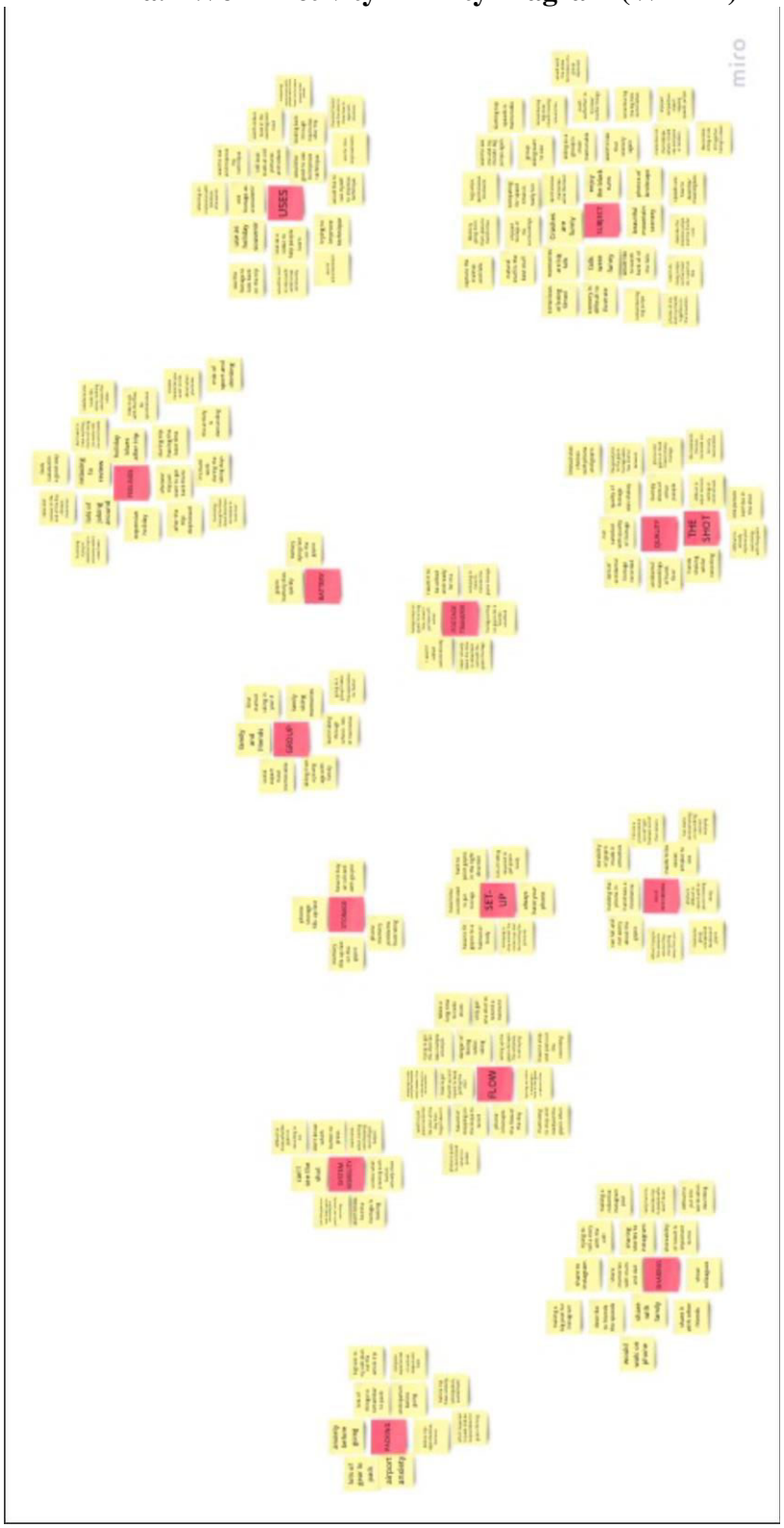
1. Can you tell me about your skiing memories, specifically the highlights of any trips?
2. Please could you describe your feelings leading up to, during, and after a skiing trip.
3. How do you feel when you describe your trip to a friend?

4. What parts of your skiing would you want captured, if any? (Prompts might be crashes, jumps, touring, group skiing, off piste, fast segments)
5. Do you think you would have any uses for skiing footage, if so, what might they be?

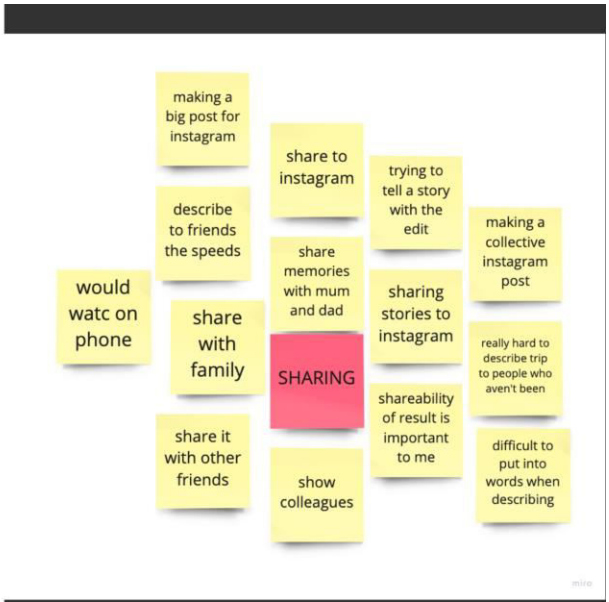
6. Have you used any of the following to capture ski film footage (GoPro, mobile phone, SkiLine SkiMovie, or anything else)?
    a. Can you describe the process of using this (from deciding you wanted to use it, to getting to the end video)?
    b. How did you feel at each stage of this process?
    c. What made you choose this option?
    d. Was it easy to use?
    e. Were you happy with the resulting footage?
    f. What would you improve about the experience of using this?
    g. How did this option compare to X option?

C. Appendix C – Data Models

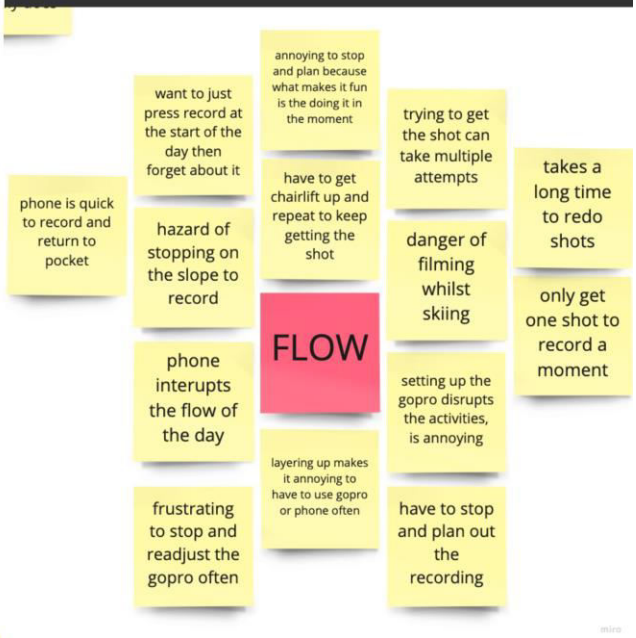
a. Work Activity Affinity Diagram (WAAD)

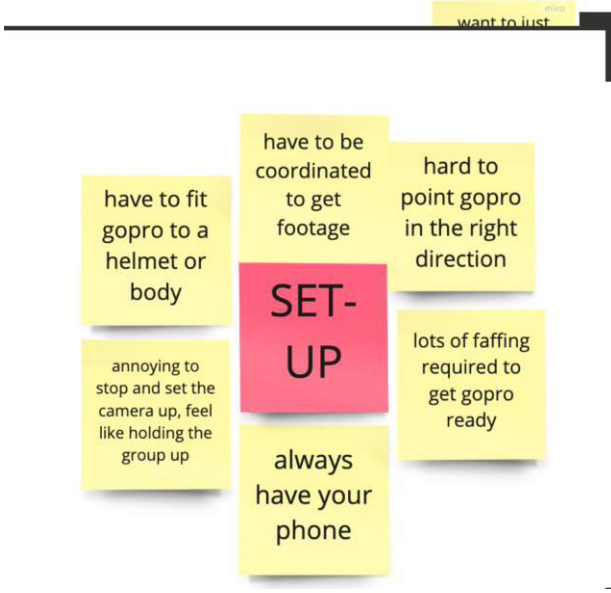


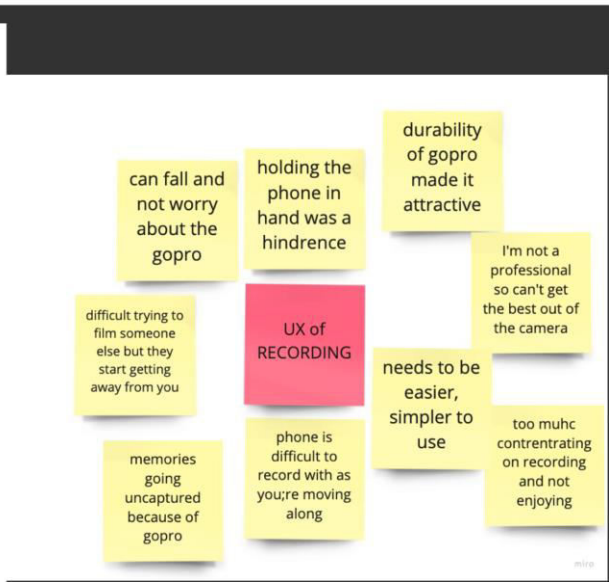
lots of gear to pack
anxiety before going
lots of things to remember to pack
big task to try adn plan out the whole trip
airport anxiety
PACKING
anticipation before going
compare experiences on actual slopes and bars
Before trip: apprehensive, nervous
before trip have anxiety, anticipation, excitement
effort required to pack and be responsible for gopro filming

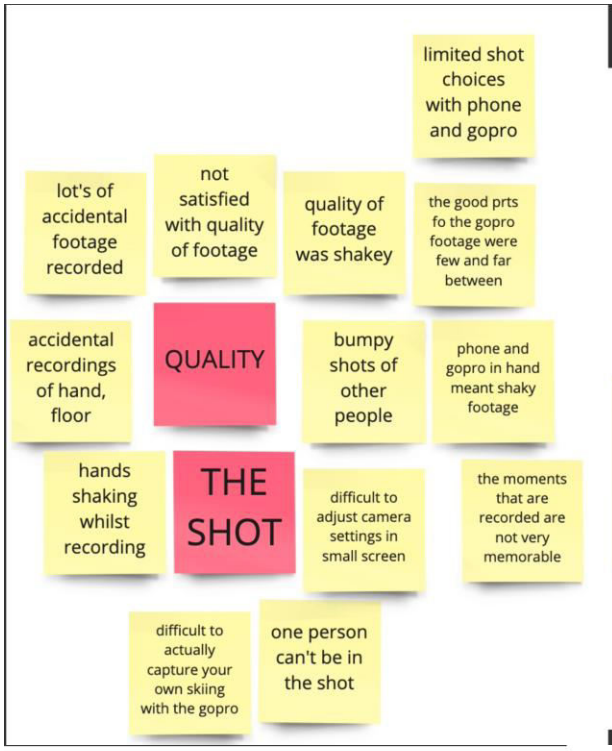

making a big post for instagram
share to instagram
trying to tell a story with the edit
making a collective instagram post
describe to friends the speeds
share memories with mum and dad
would watc on phone
share with family
sharing stories to instagram
SHARING
really hard to describe trip to people who aven't been
shareability of result is important to me
share it with other friends
difficult to put into words when describing
show colleagues

difficult to know whether gopro is recording or not
can't see the shot
put the gopro on and think you're recording but you're not actually recording
don't know which button to press
SYSTEM VISIBILITY
don't know hot the footage is looking
loud noise when starting and stopping recording is helpful
unclear what pressing each button actually does

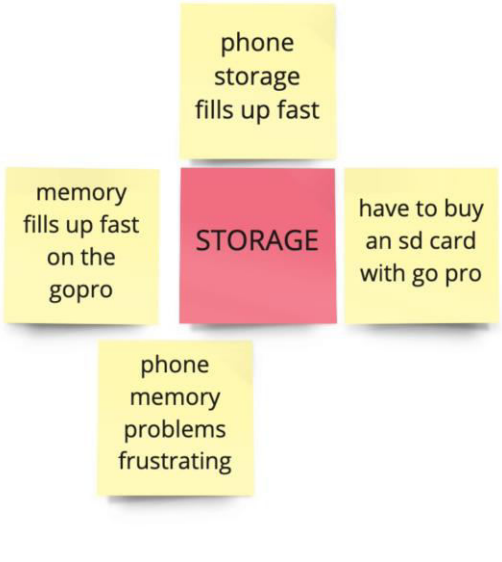

annoying to stop and plan because what makes it fun is the doing it in the moment
want to just press record at the start of the day then forget about it
trying to get the shot can take multiple attempts
takes a long time to redo shots
phone is quick to record and return to pocket
have to get chairlift up and repeat to keep getting the shot
hazard of stopping on the slope to record
danger of filming whilst skiing
FLOW
only get one shot to record a moment
phone interupts the flow of the day
setting up the gopro disrupts the activities, is annoying
layering up makes it annoying to have to use gopro or phone often
frustrating to stop and readjust the gopro often
have to stop and plan out the recording


have to be coordinated to get footage
hard to point gopro in the right direction
have to fit gopro to a helmet or body
SET-UP
lots of faffing required to get gopro ready
annoying to stop and set the camera up, feel like holding the group up
always have your phone

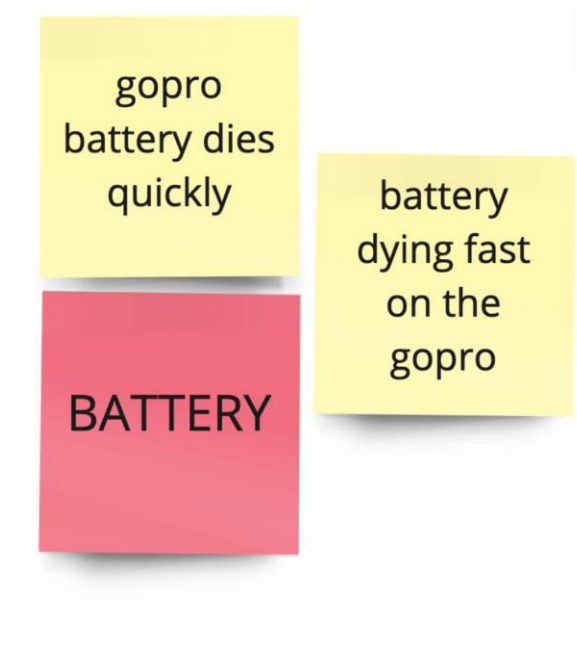

durability of gopro made it attractive
can fall and not worry about the gopro
holding the phone in hand was a hindrence
I'm not a professional so can't get the best out of the camera
difficult trying to film someone else but they start getting away from you
UX of RECORDING
needs to be easier, simpler to use
too muhc contrentrating on recording and not enjoying
memories going uncaptured because of gopro
phone is difficult to record with as you;re moving along

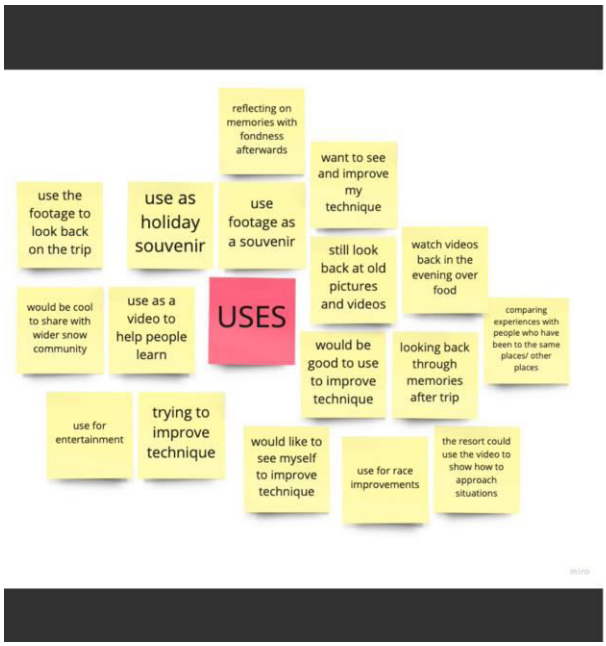

limited shot choices with phone and gopro
lot's of accidental footage recorded
not satisfied with quality of footage
quality of footage was shakey
the good prts fo the gopro footage were few and far between
accidental recordings of hand, floor
QUALITY
bumpy shots of other people
phone and gopro in hand meant shaky footage
hands shaking whilst recording
THE SHOT
difficult to adjust camera settings in small screen
the moments that are recorded are not very memorable
difficult to actually capture your own skiing with the gopro
one person can't be in the shot

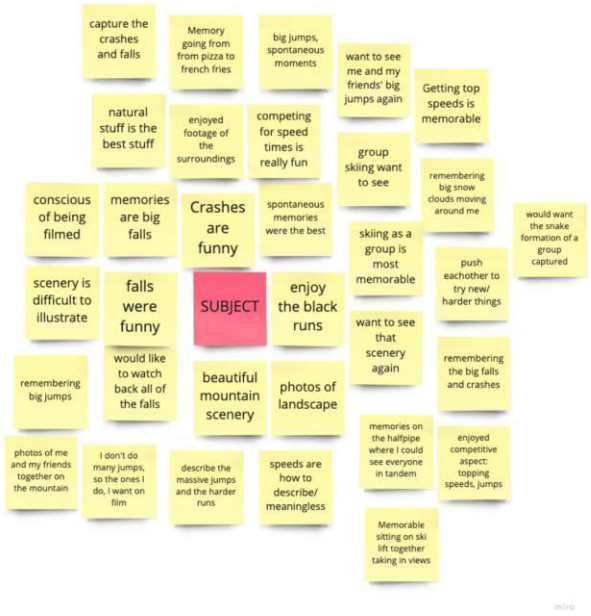
footage stays on gopro for a long time, doesn't get taken off/ edited
I want it edited automatically
I want it to be edited and ready for me
FOOTAGE TRANSFER
never actually taken the time to download and edit the gopro footage
annoying to have to transfer the gopro footage
footage sitting on gopro for 6 months unedited


phone storage fills up fast
memory fills up fast on the gopro
STORAGE
have to buy an sd card with go pro
phone memory problems frustrating

family and friends
First started skiing in year 4
social aspect most memorable
GROUP
family skiing memories
skiing from a young age with family
learnt skiing through school - lots of memories
going as a group makes the experience far better







b. User Personas

<u>Persona 1: Sam, a studio assistant</u>

- Name: Sam Kyle
- Occupation: Works as a movie studio assistant on a freelance basis
- Demographic: 27 years old, lives in London. Single but dating, has a middle-income level.

Sam's story:

Sam is working as a movie studio assistant on a freelance basis, which can be stressful when not knowing what the next job might be, but incredibly rewarding to see the results of his work being enjoyed by millions. The work is physical, and Sam is on his feet all day, this is extra taxing as studio's run seven days a week. Sam has been skiing since he was a child and has become great at doing tricks and jumps. Sam enjoys going on one weeklong skiing holiday every year with friends.

What challenges Sam:

Time is a challenge for Sam as his work is very demanding, meaning that he doesn't have much free time to himself. Therefore, he enjoys a holiday so much because it is a rare time where he can fully relax and let his mind rest for a week. Sam would like to share his skiing moments, especially his jumps and tricks, with his friends online. Also, at 27 years old he's conscious of getting older and would like to capture his skiing memories with his friends to have something to look back on.

What Sam needs:

Sam needs a product that will capture his tricks, jumps, and most memorable skiing moments with his friends. He needs the product to take up as little of his time as possible, before, during, and after the holiday, he doesn't want to have to think about it. In addition, he wants the result of that capture to be shareable on social media with his other friends in his demographic. The product needs to capture the spontaneous skiing moments which make Sam's holiday so special.

<u>Persona 2: Caitlin, a consultant</u>

- Name: Caitlin Myles
- Occupation: Is a partner in a top management consulting agency
- Demographic: 40 years old, lives in Manchester. Wife to Darren Myles, another consulting partner, and mother to Maisy (10) and Paul (8). The family are upper-income level.

Caitlin's story:

After working her way to a partner position at a prestigious consulting company, Caitlin likes to enjoy luxurious holidays and get the very best experience for her and her family. The family's favourite holiday is a skiing holiday where they rent out a private villa with a hot tub for two weeks. Caitlin works hard and loves her family very much; she is aware that her children are growing up quickly and wants to slow down time with them.

What challenges Caitlin:

Caitlin adores her children, the only challenge being that they rarely want to sit still for photographs or videos. This is difficult because they are growing so fast, and she wants memories of them to look back on and share with their grandparents who are retired and often away from home. She wants to be able to see how her child is improving in their ski lessons and share this with their extended family.

What Caitlin needs:

Caitlin needs a product which captures her children growing and developing in their skiing lessons. This will be used for own family memories, and to be shared with extended family. However, the product needs to be discrete to the extent that her children are not disrupted by the product and therefore don't mind being recorded by it because they can go about their skiing without interruption.

c. User Stories

As a mother of two young children, I want to capture memories from their childhood so that we, as a family, can have things to look back on as the children grow up.

As a young male in his twenties, I want to capture video of myself doing skiing tricks to share with friends online.

As a teen on a skiing school trip, I want to capture video of myself skiing so that my parents have a piece of mind.

As a female in her twenties, I want to capture video of my ski jumps so that I can improve my technique.

As a male in his twenties, I want to capture group skiing clips so that I have a memento from my holiday.

As a father I want to capture video of myself skiing to share with my family abroad.

As a member of a strong skiing community, I want to capture video of myself skiing so that others in the community can rate my skills.

As a member of a skiing community, I want to capture video of the resort conditions so that others in the community can assess whether they'd like to visit.

As a ski resort promoter, I want to capture video of how much of a brilliant experience this resort is so that people can see and be attracted to come.

As a mother taking her children on their first skiing holiday, I want to capture video of their experience because it's unlikely that we will be able to come again soon.

As a travelling vlogger I want to capture video of myself skiing so that I have exciting content to share with my followers.

As a skiing vlogger I want to capture video of myself doing new tricks so that my followers can keep up to date with my progress.

As an Olympic skier I want to video of myself performing jumps so that I can analyse and improve my technique.

d. User Story of GoPro Usage

If I'm using a GoPro to capture footage on a skiing trip, I first must remember to bring the GoPro and its accessories with me whilst packing. I don't use the GoPro every week, so I have to dig through my drawers to find the camera and its batteries, cases, and mounts. I also need to find the micro-SD card that I use with the GoPro and empty out its contents before going on the trip. To do this I have to find the SD card adapter for my laptop and then transfer the files. After this, I pack the GoPro, SD card, batteries, and accessories in my luggage.

When I arrive at the skiing accommodation, I immediately plug the GoPro in for use the next day (this means using another precious plug point). On the morning of skiing, amongst all the other busy activities, I decide on which harness/ mount to use and get a friend to help fit it to me. I take the batteries and the GoPro out in my pocket.

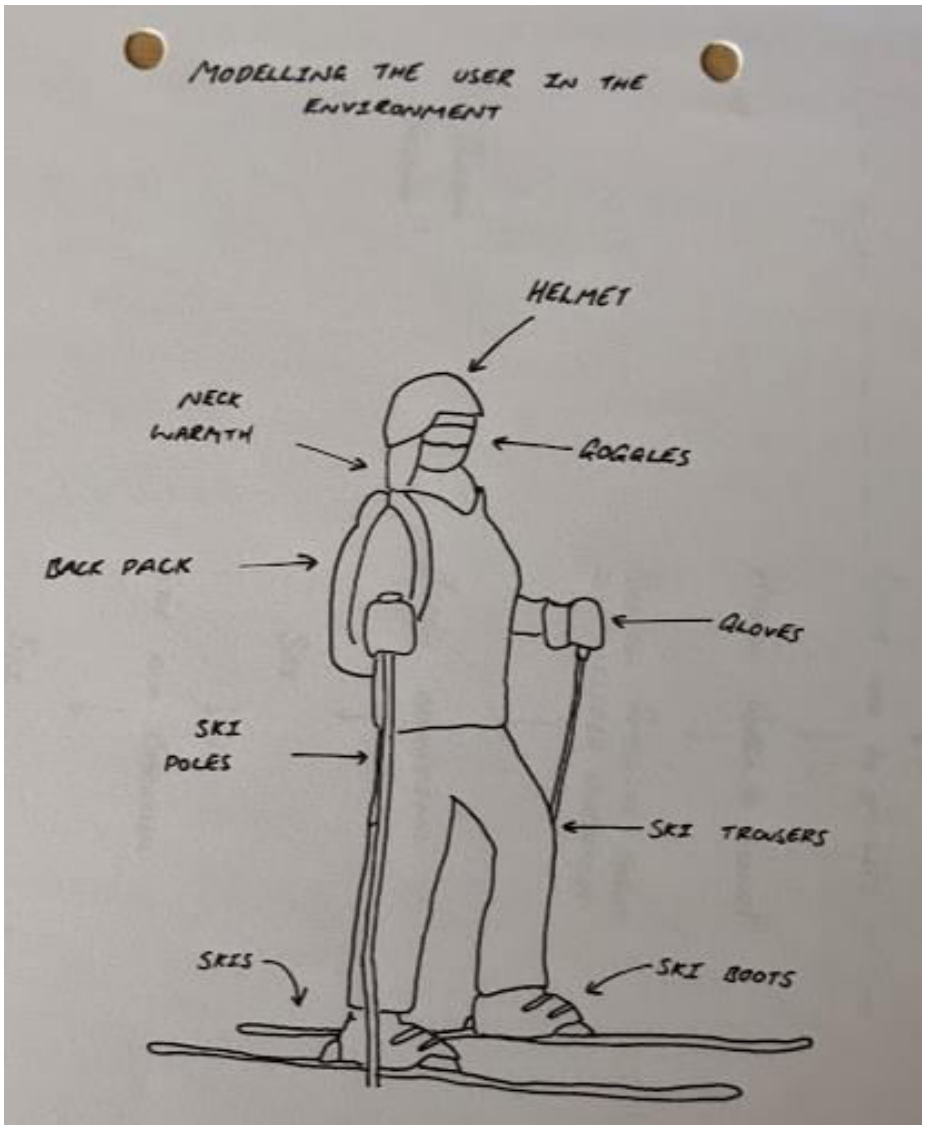
At the top of a run, I want to film, I ask the group to stop and wait whilst I attach the GoPro. I try to guess which direction it's facing and what it will capture. I tell the group that I'll stay behind the, as I'll be able to capture what's infront of me. I remove my gloves, attach the GoPro, and we set off.

Halfway through the run, my friend does a cool and spontaneous trick by jumping off a ledge over another friend. I was too far away to have captured it. We stop and decide it was a cool moment that we should try to get on film. We do the lift and run again. This time, I go ahead, stopping and waiting in a position that would let me record the jump. Some other skiiers ski near me (I'm a little bit in the way), but this is what is needed to get the shot. My friends approach the jump and almost complete it again, but this time they just miss and the trick flops.

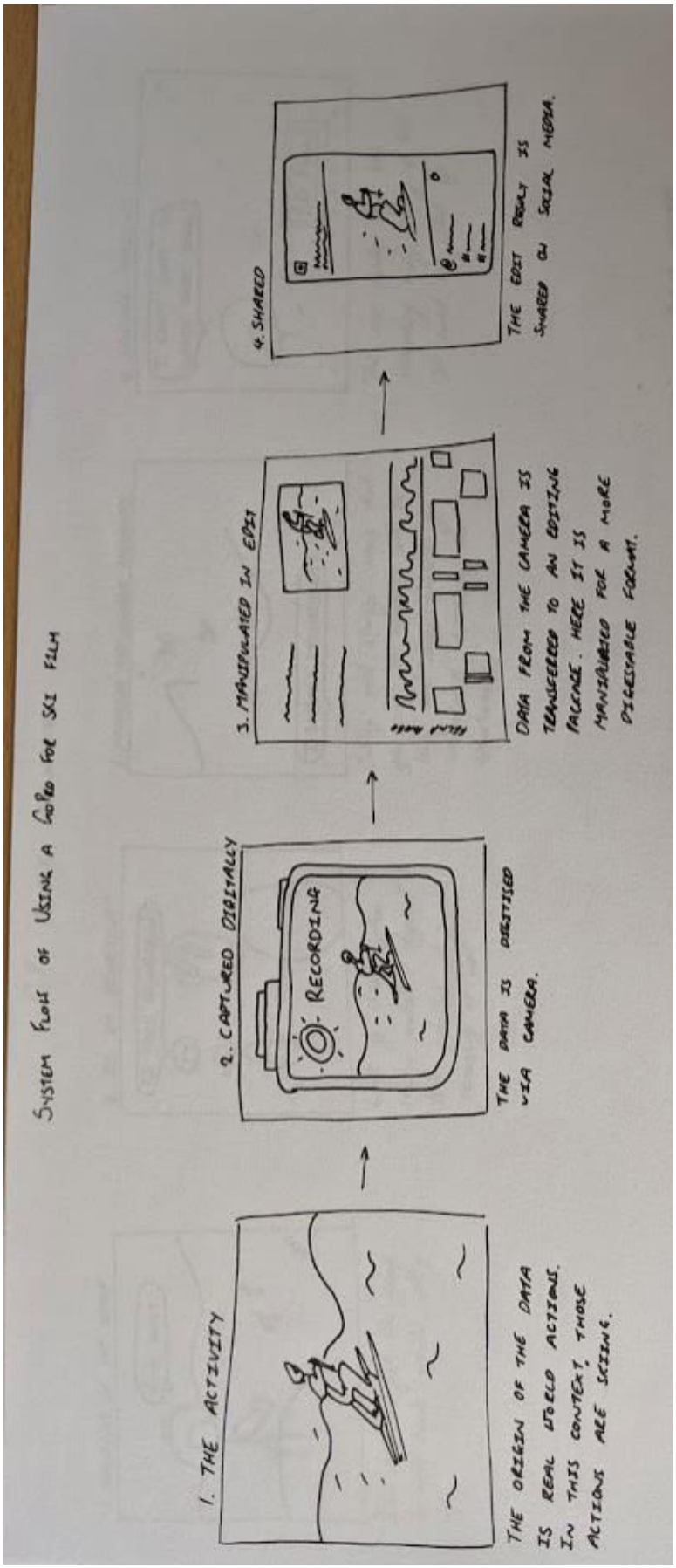
We ski down to the bottom of the slope to try and review the footage. The small screen and sun glare means we can't see much and decide to wait until we're back at the resort to review it. I dig to the bottom of my bag to find the SD adaptor to allow me to transfer the footage, however it seems I've forgotten it, so we just use the GoPro screen to review. It's clear the shot isn't great.

After the trip I must go back to work the next day. The footage sits on the GoPro for 4 months until I have the time to transfer it to my laptop. Again, I find the SD adaptor and transfer the footage before beginning the edit process. By now, the trip was very far away but it's still nice to review the footage.

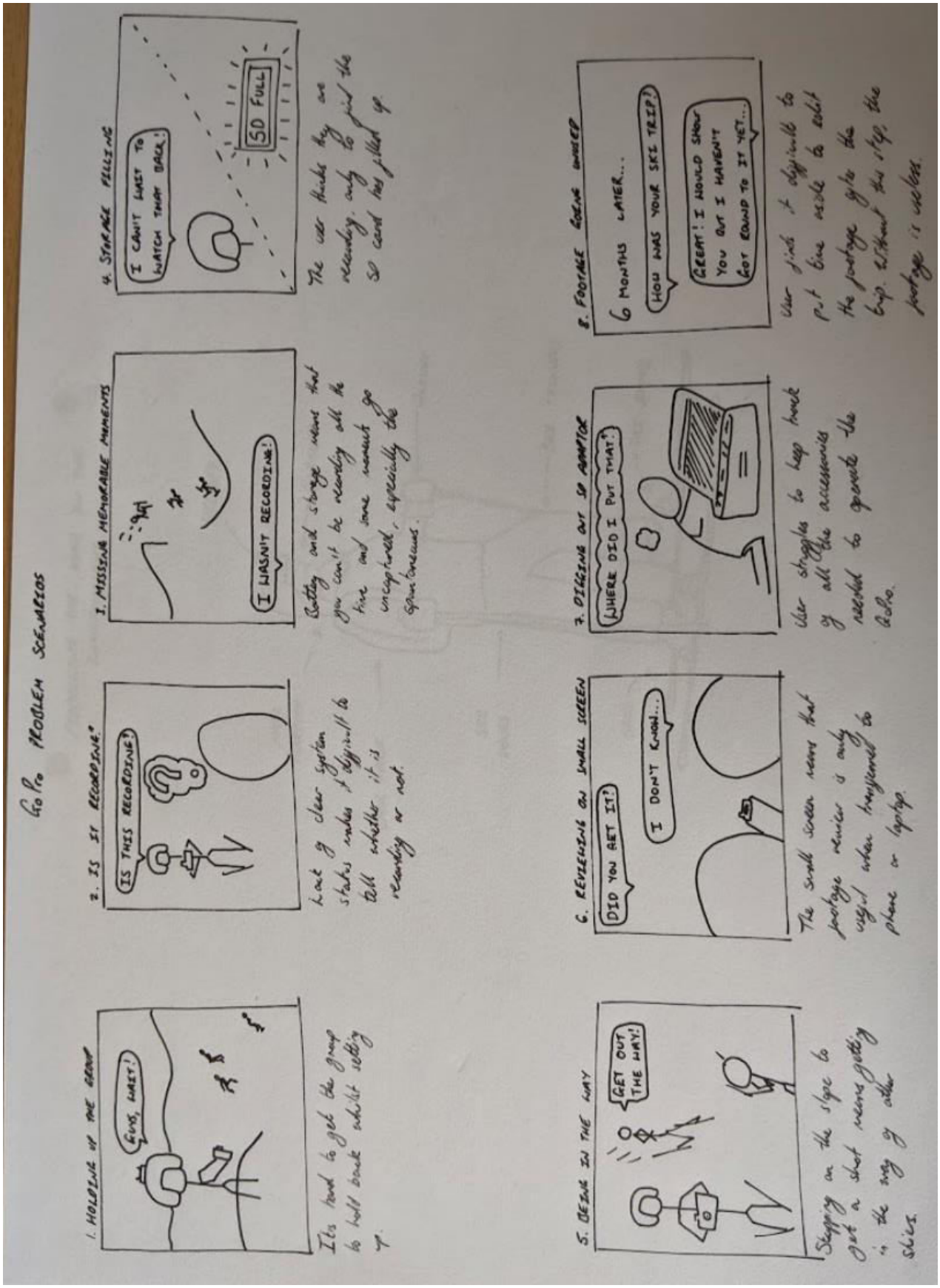
e. Modelling the User in Environment



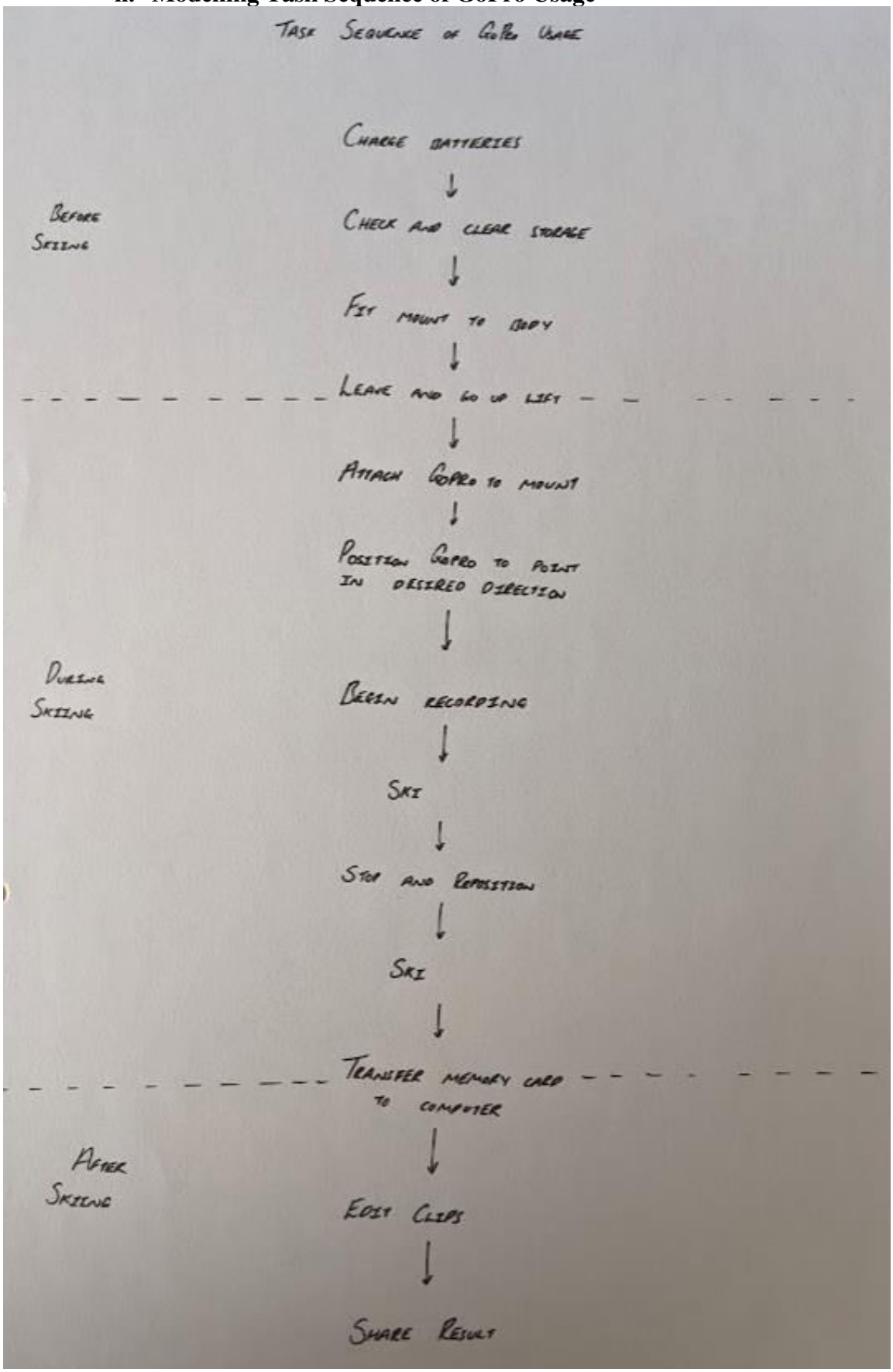
f. System Flow Model of using a GoPro for Ski Film



g. Modelling GoPro Problem Scenarios

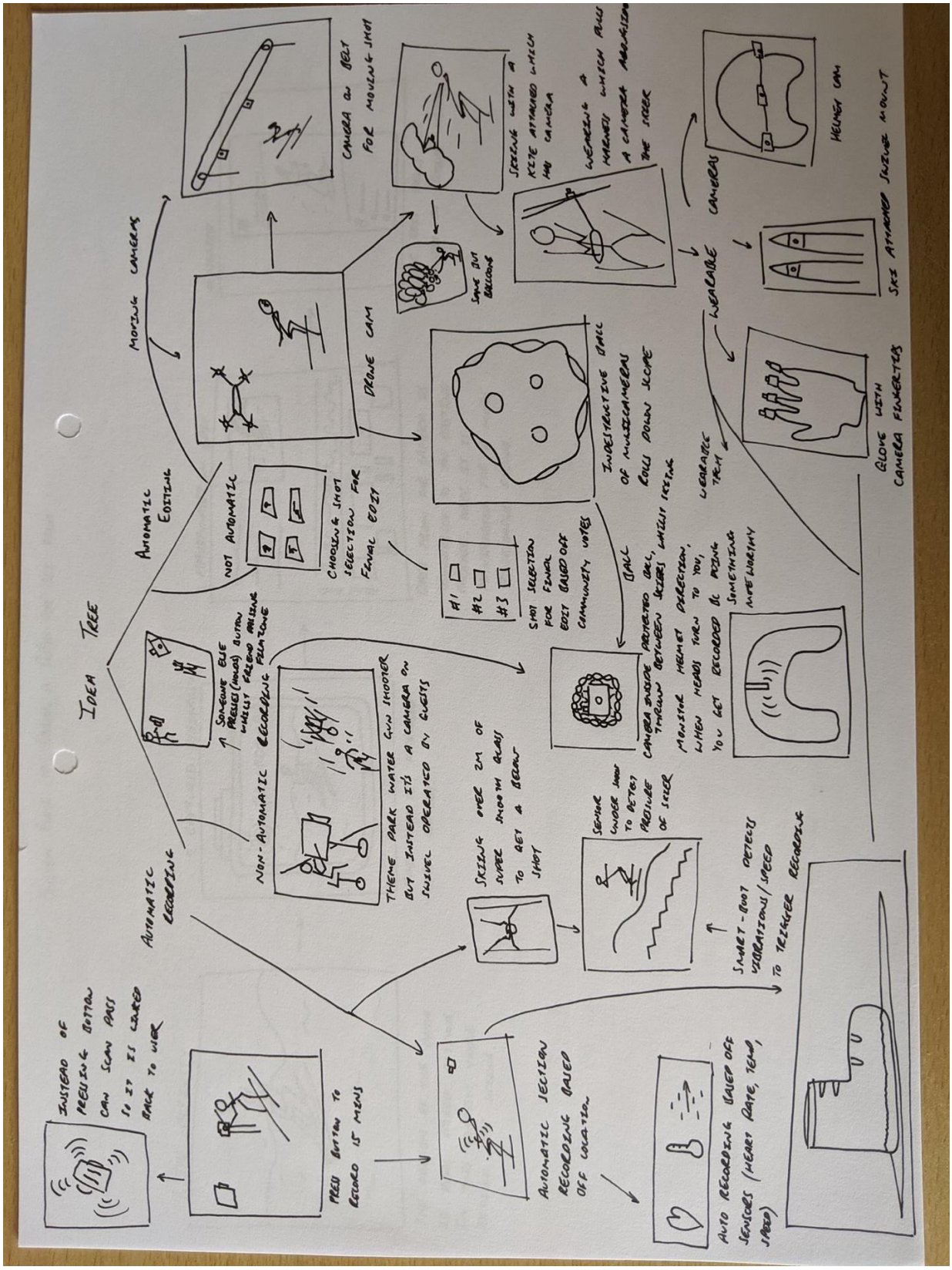


h. Modelling Task Sequence of GoPro Usage

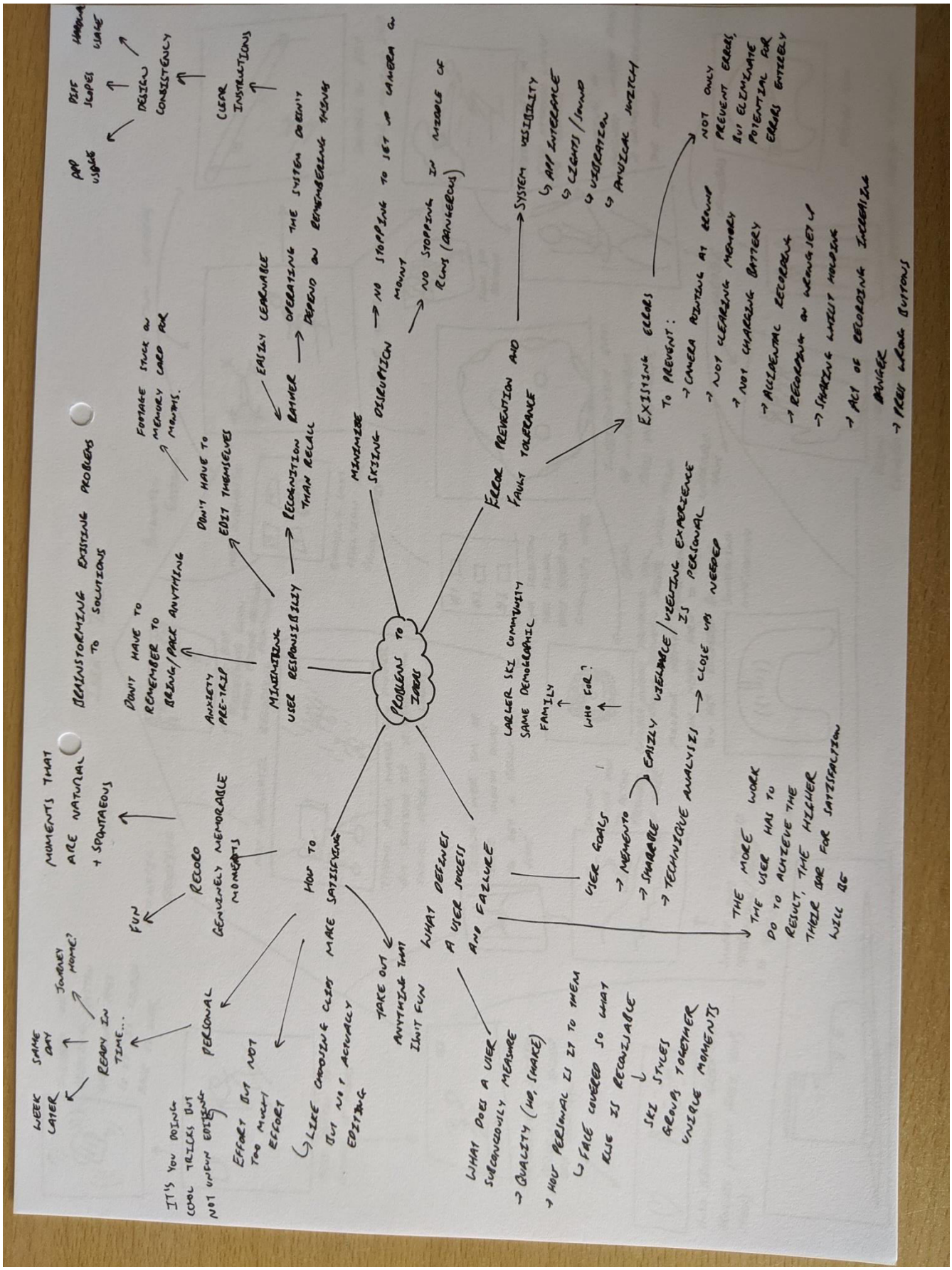


D. Appendix D – Design Process

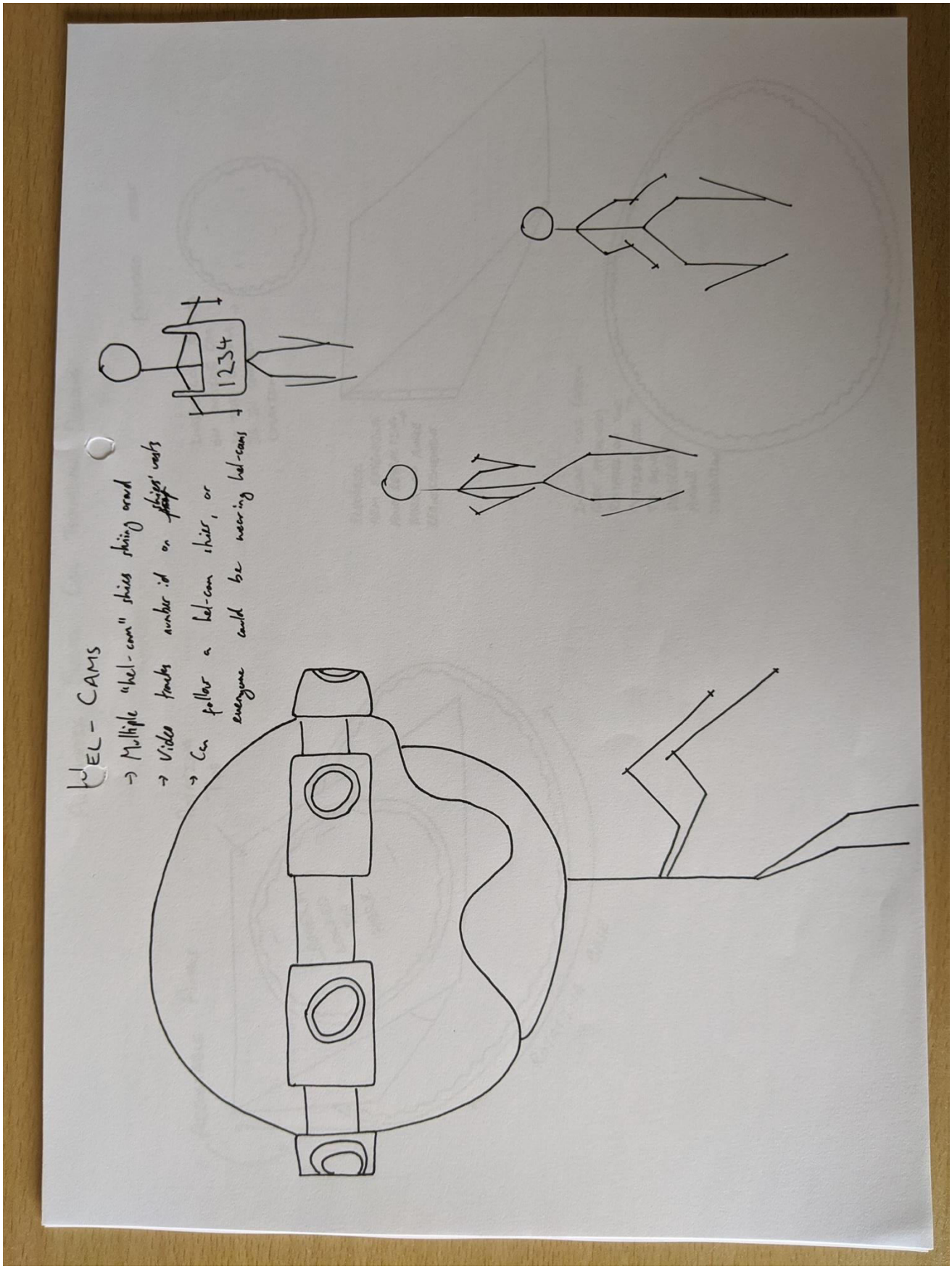
a. Idea Tree



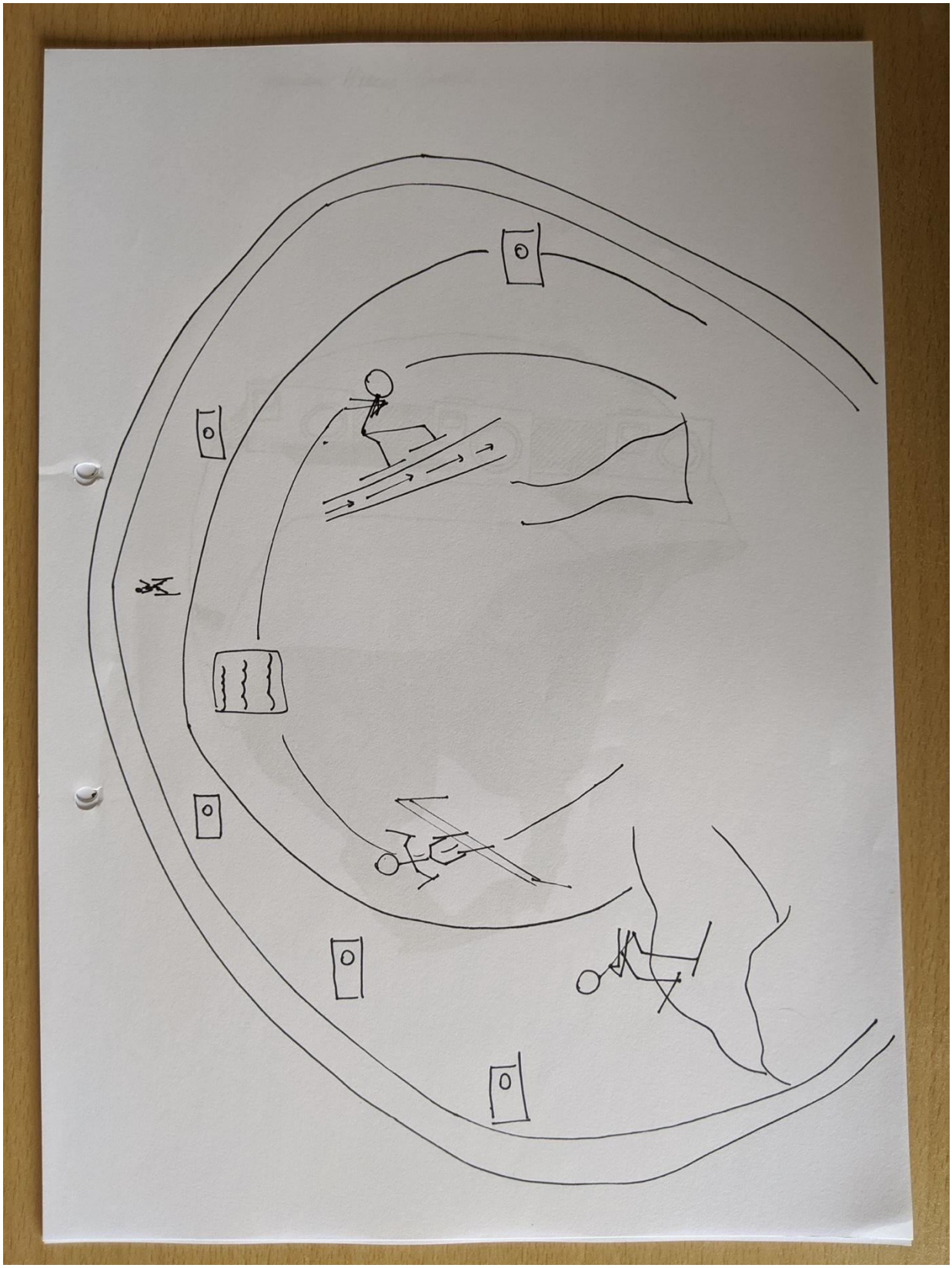
b. Mind Mapping Problems and Potential Solutions



c. Early Idea – Helcam

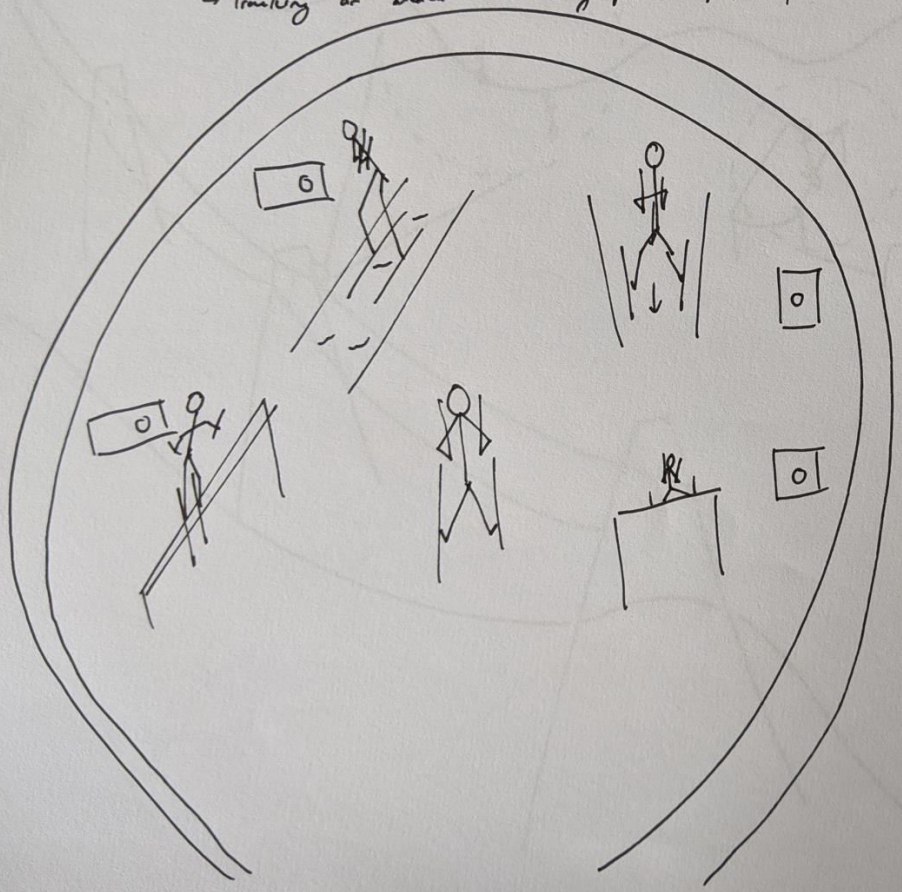


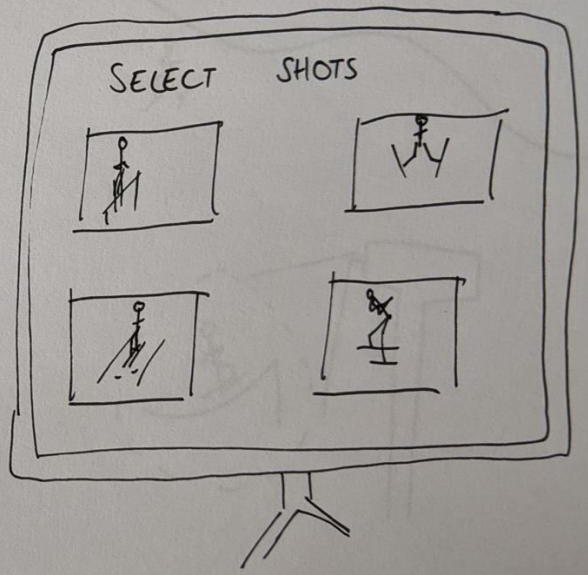
d. Early Idea – Ski Tunnel



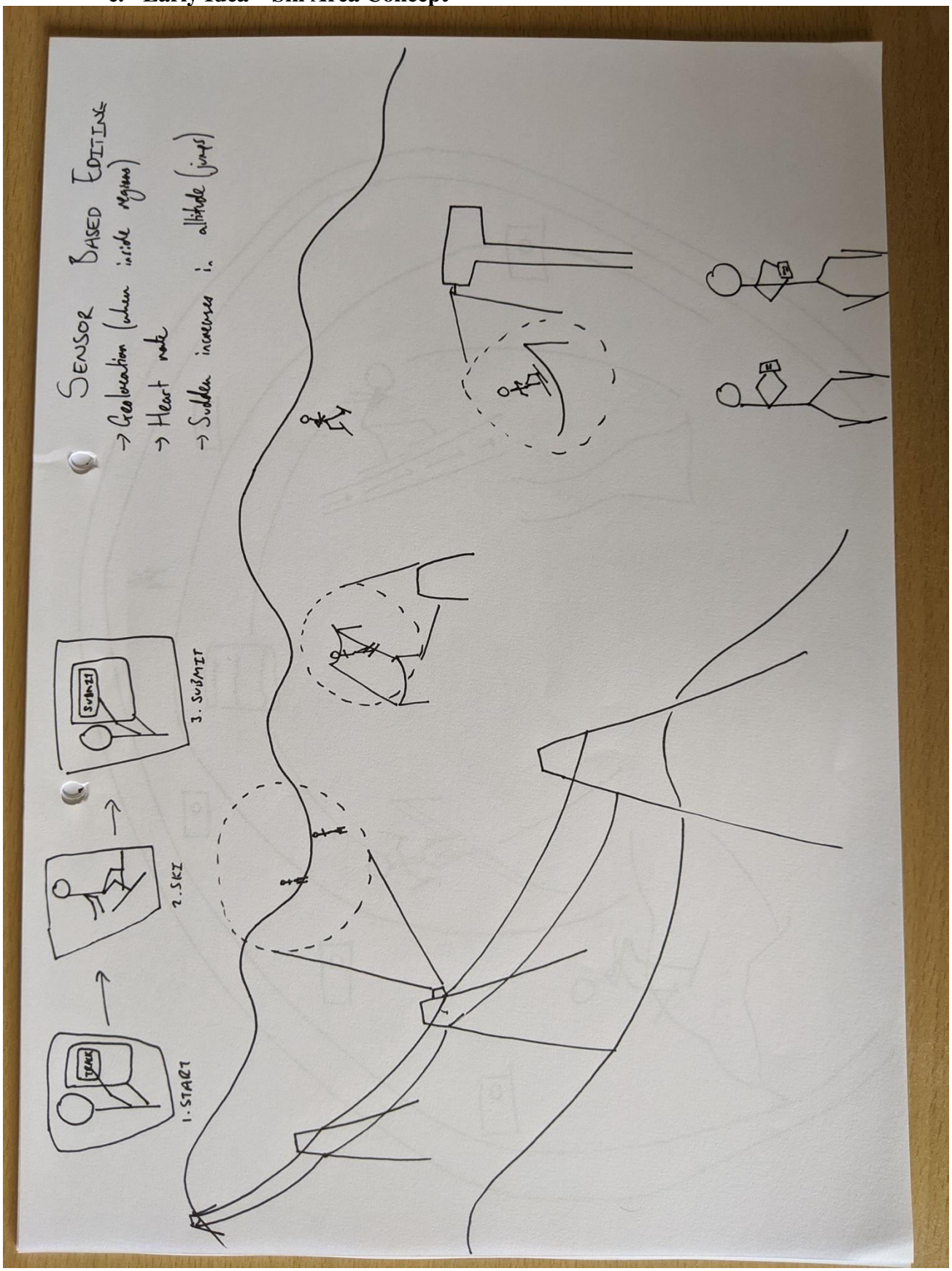
SKILL TUNNEL (Doesn't have to be in tunnel)

→ Special tunnel w/ good lighting, different sections set up
→ Sections include grind rail, jump, speed section etc.
→ Each section has its own camera
→ Afterwards, choose which sections you want included in your video
→ Trouble or ~~[illegible]~~ auto-editing pro shits, then find themselves.

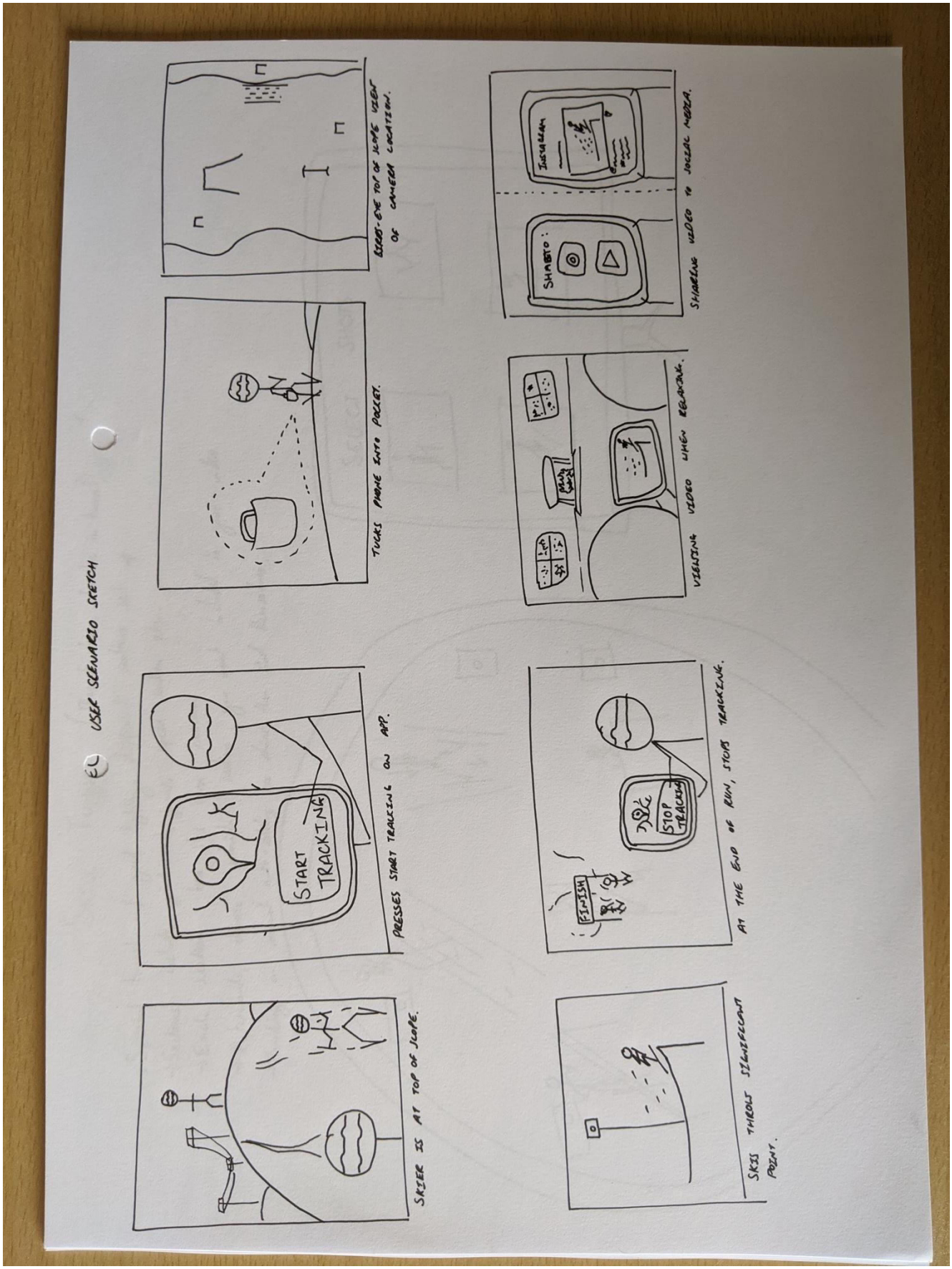




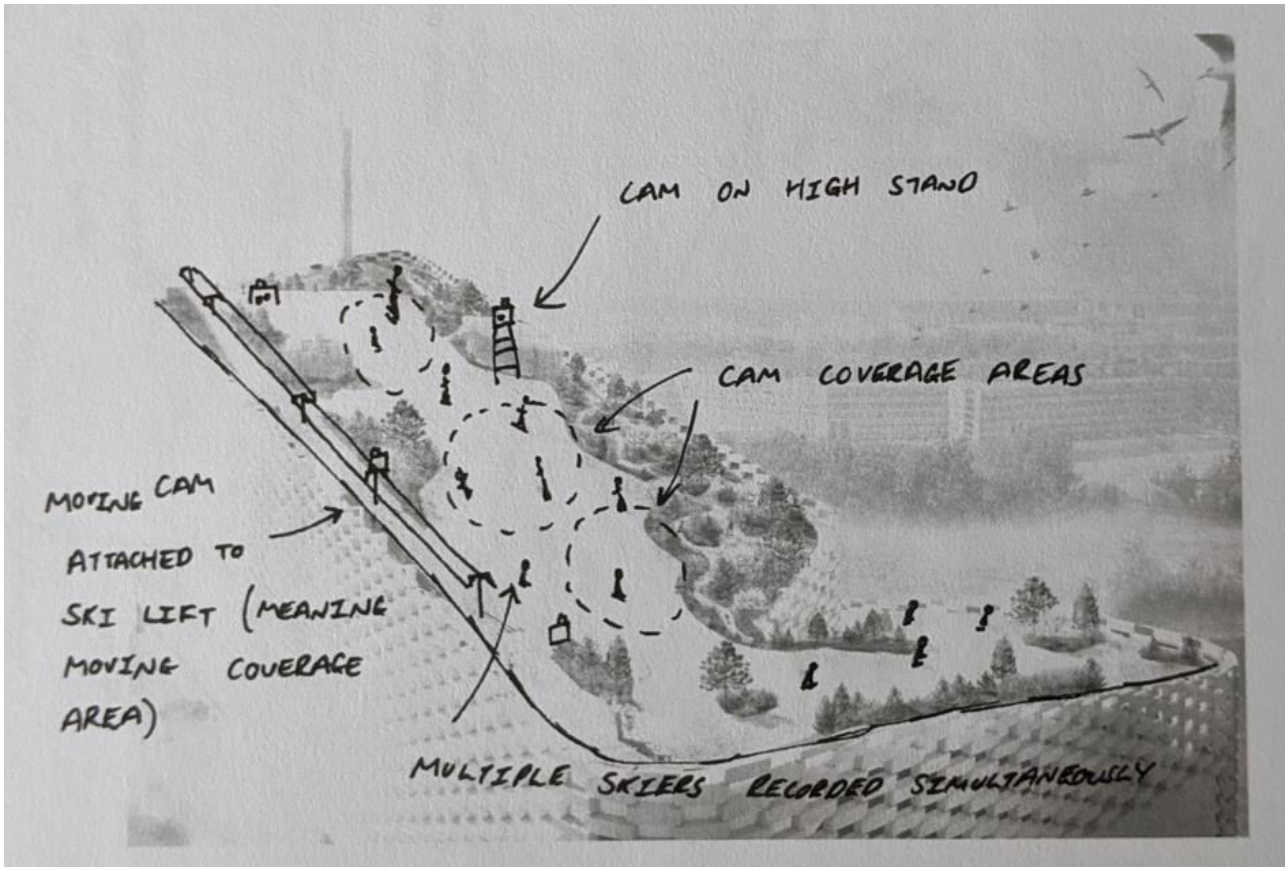
e. Early Idea – Ski Area Concept



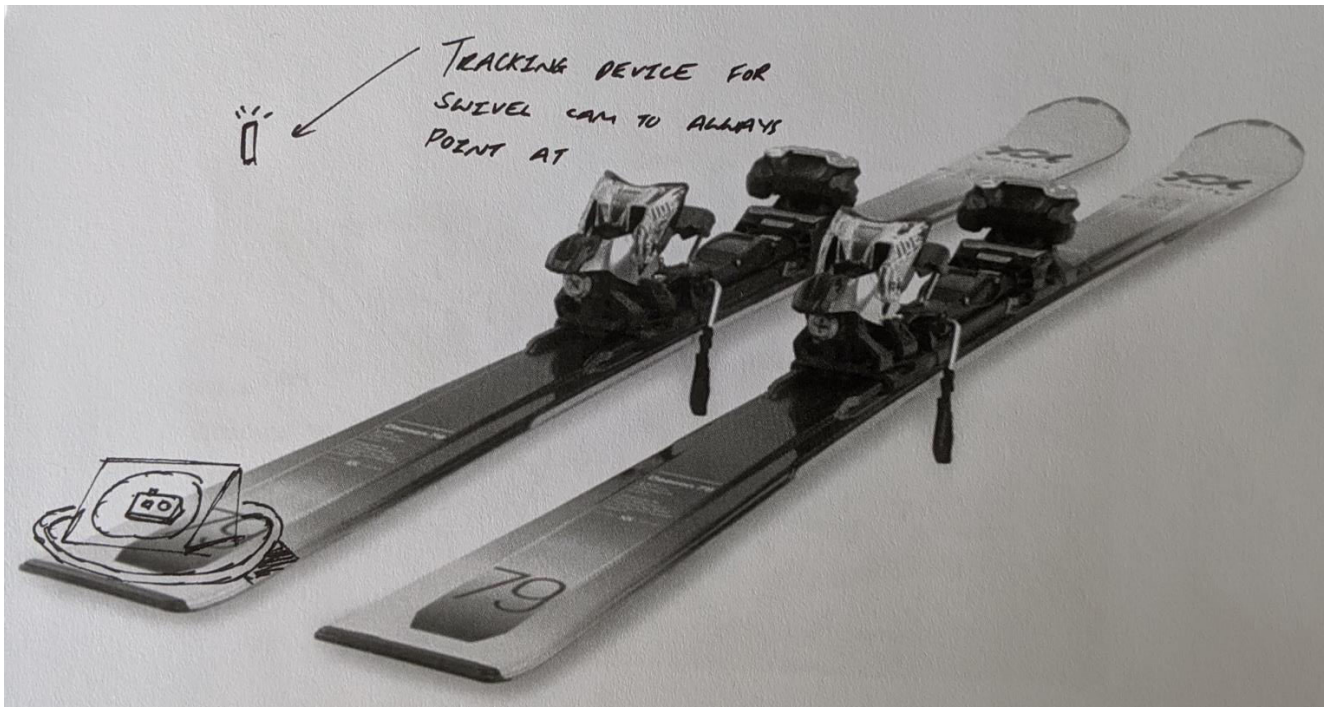
f. Early Ski Area User Scenario Sketch



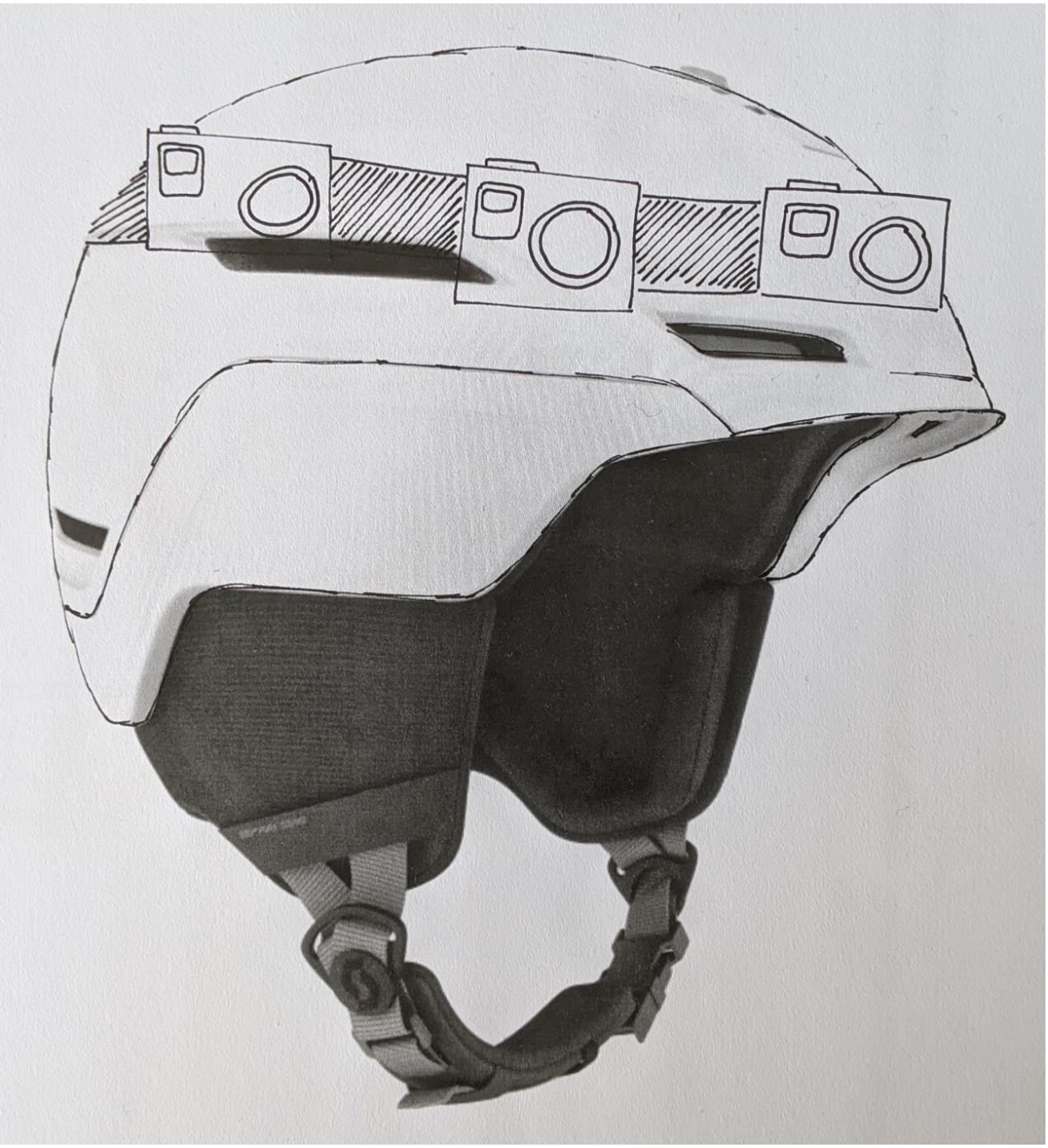
g. Ski Area Hybrid Sketch



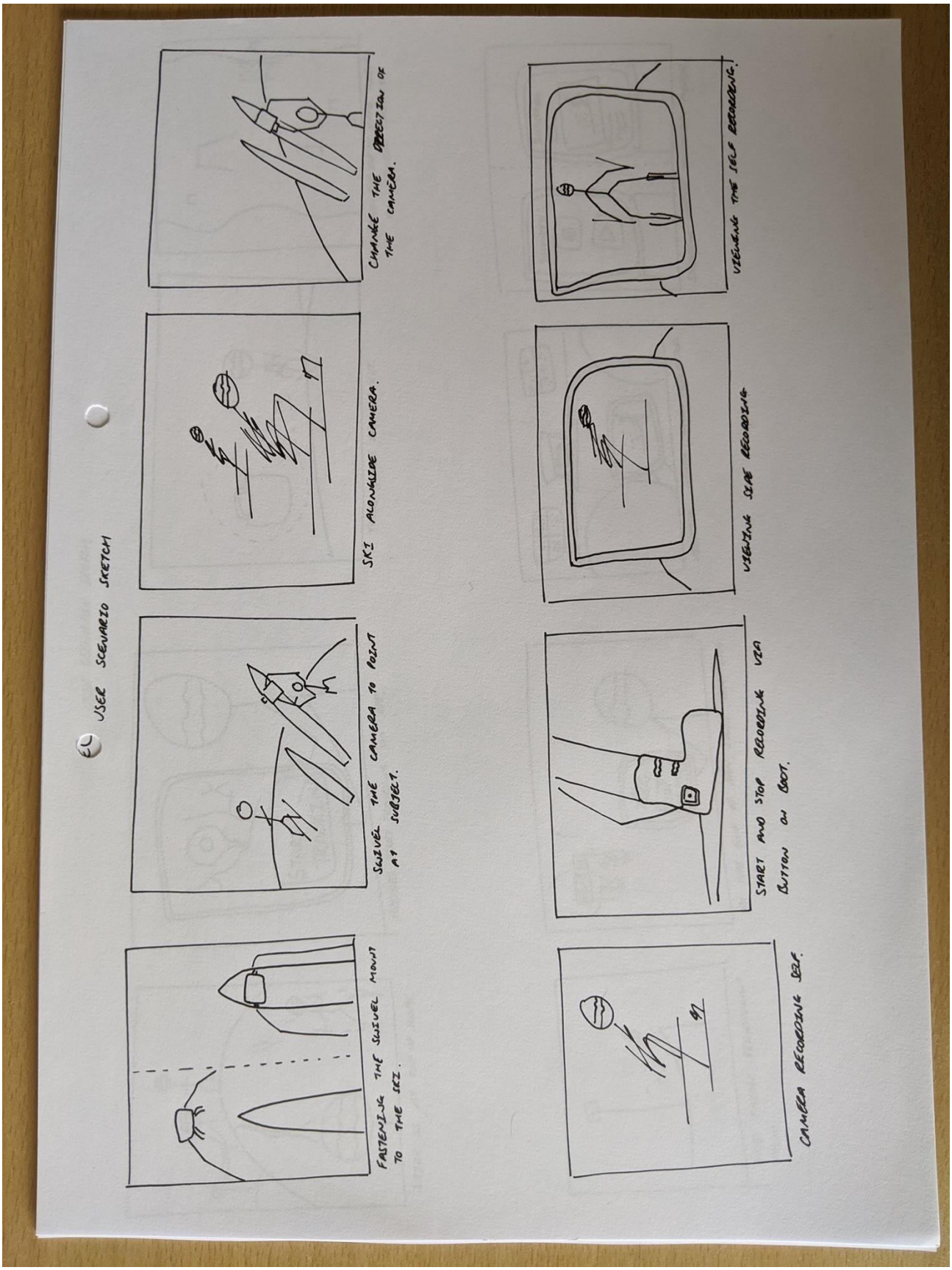
h. Swivel Cam Hybrid Sketch



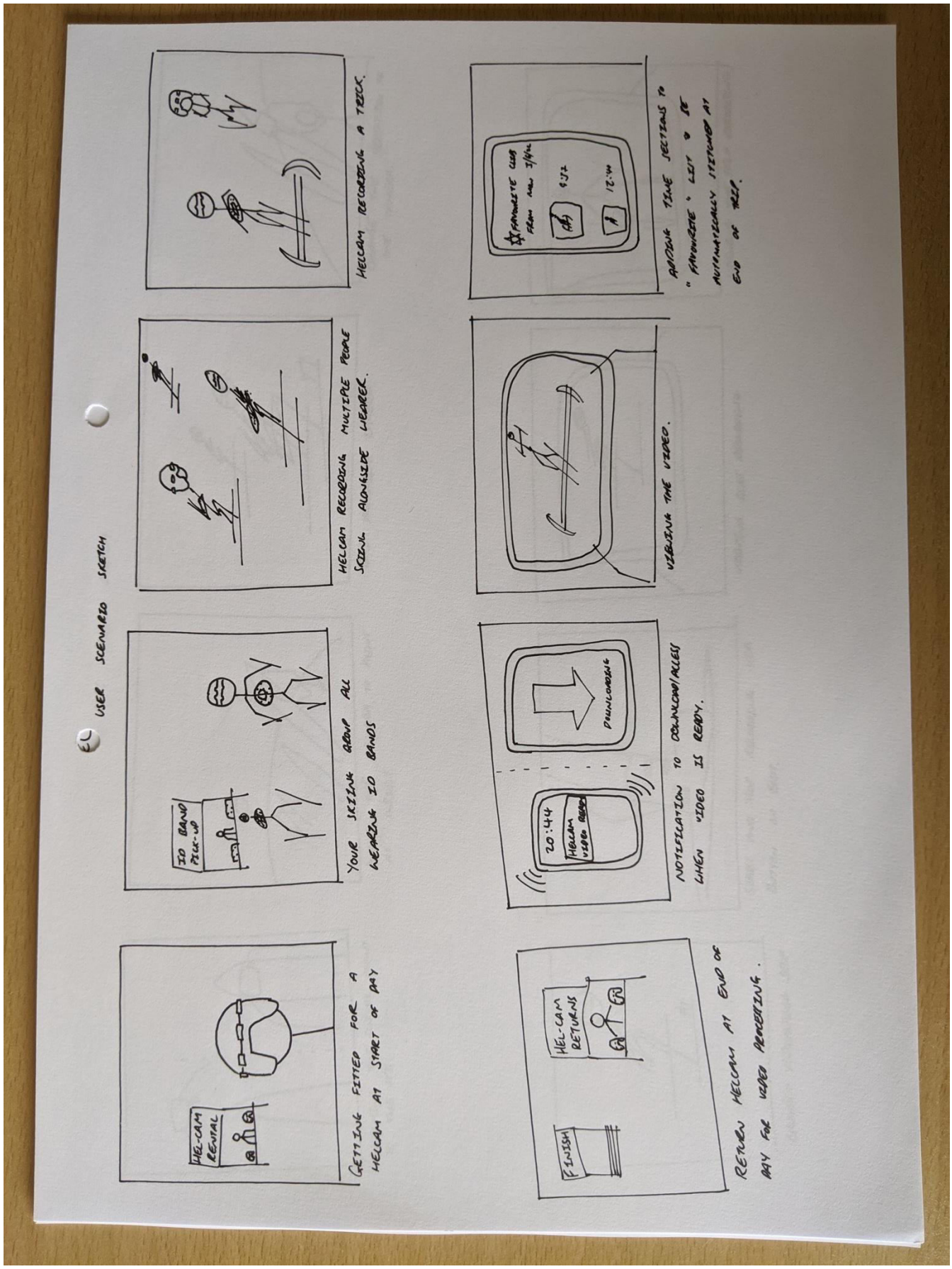
i. Helcam Hybrid Sketch



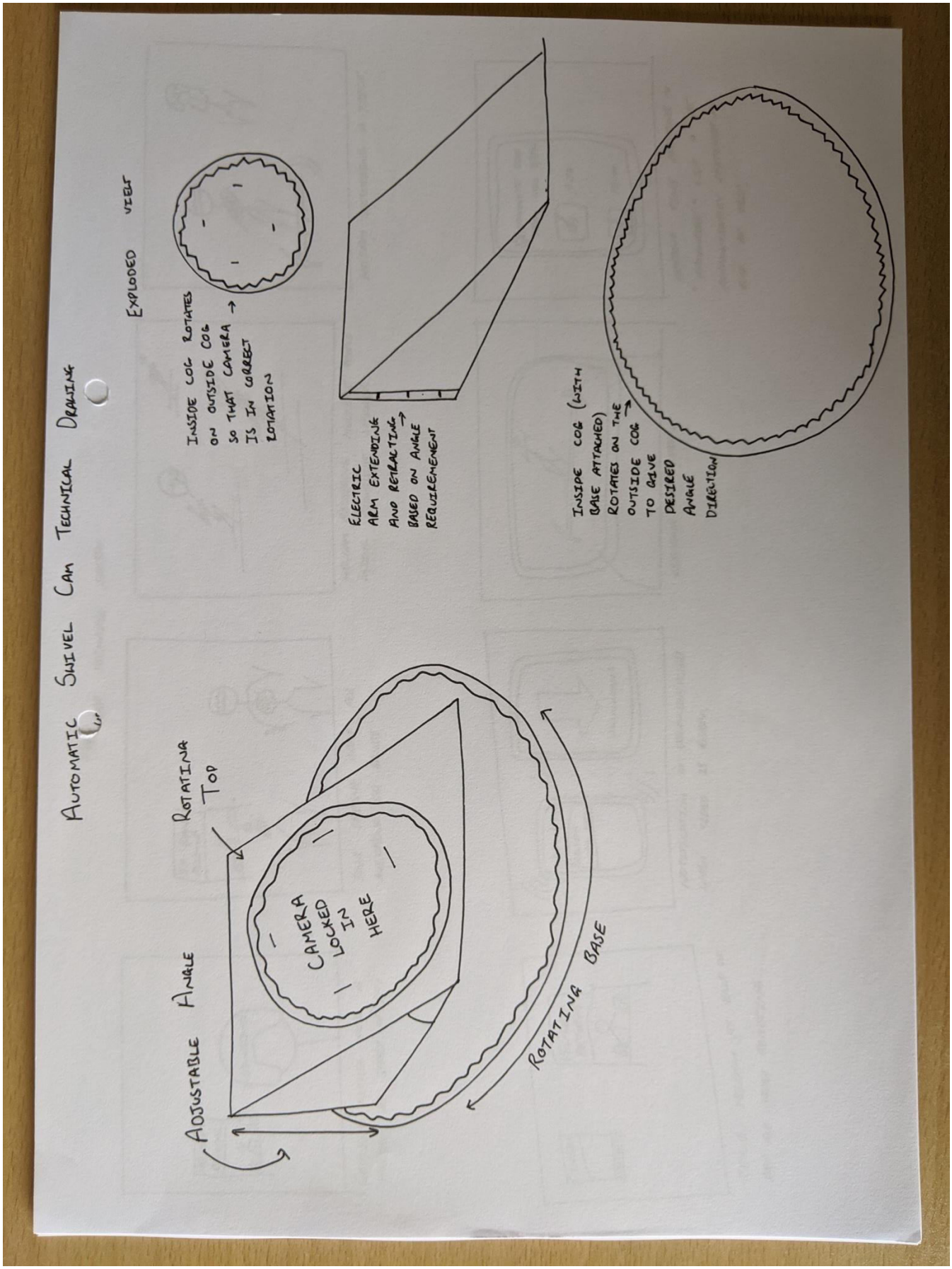
j. Swivel Mount User Scenario Sketch



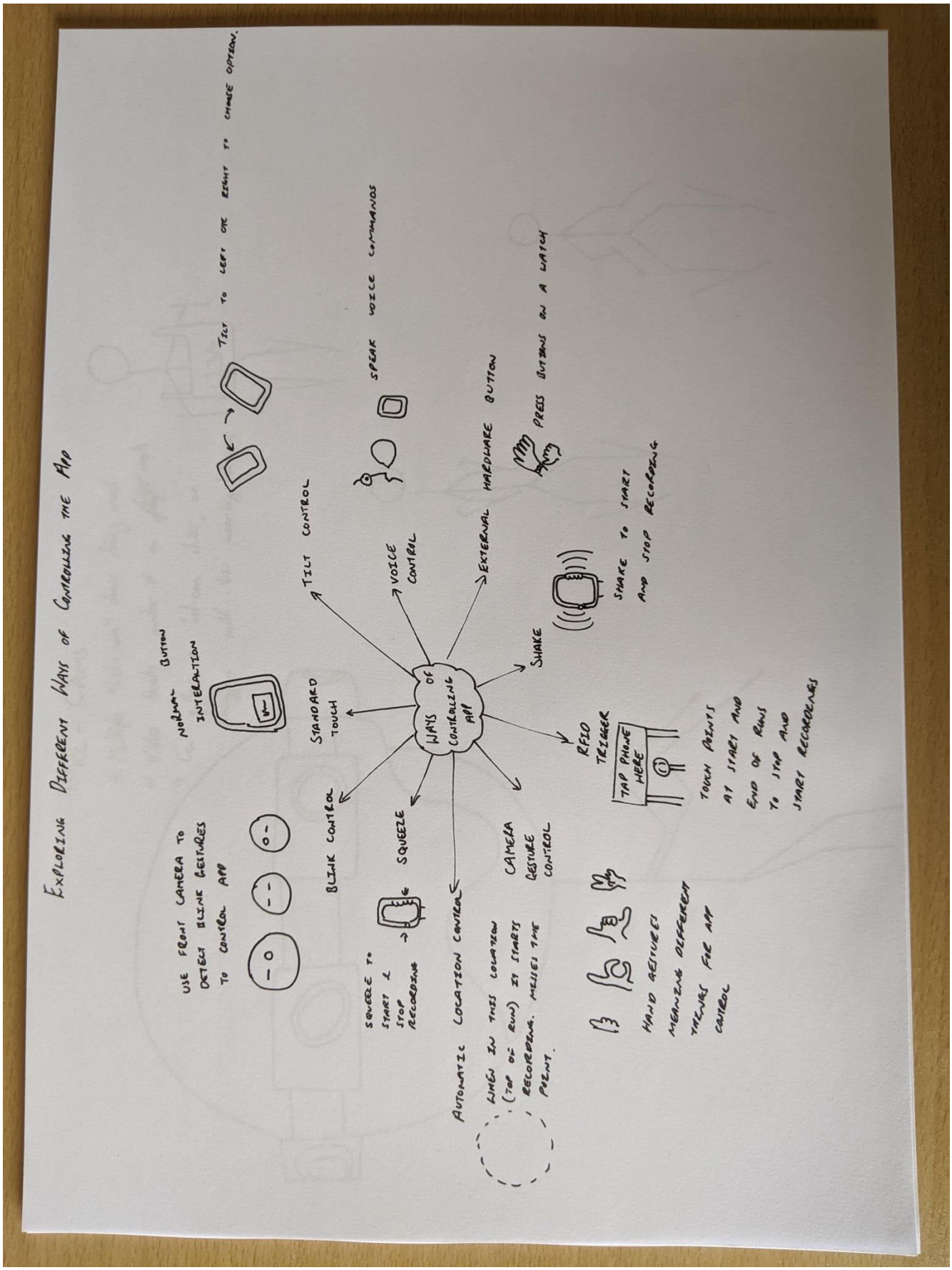
k. Helcam User Scenario Sketch



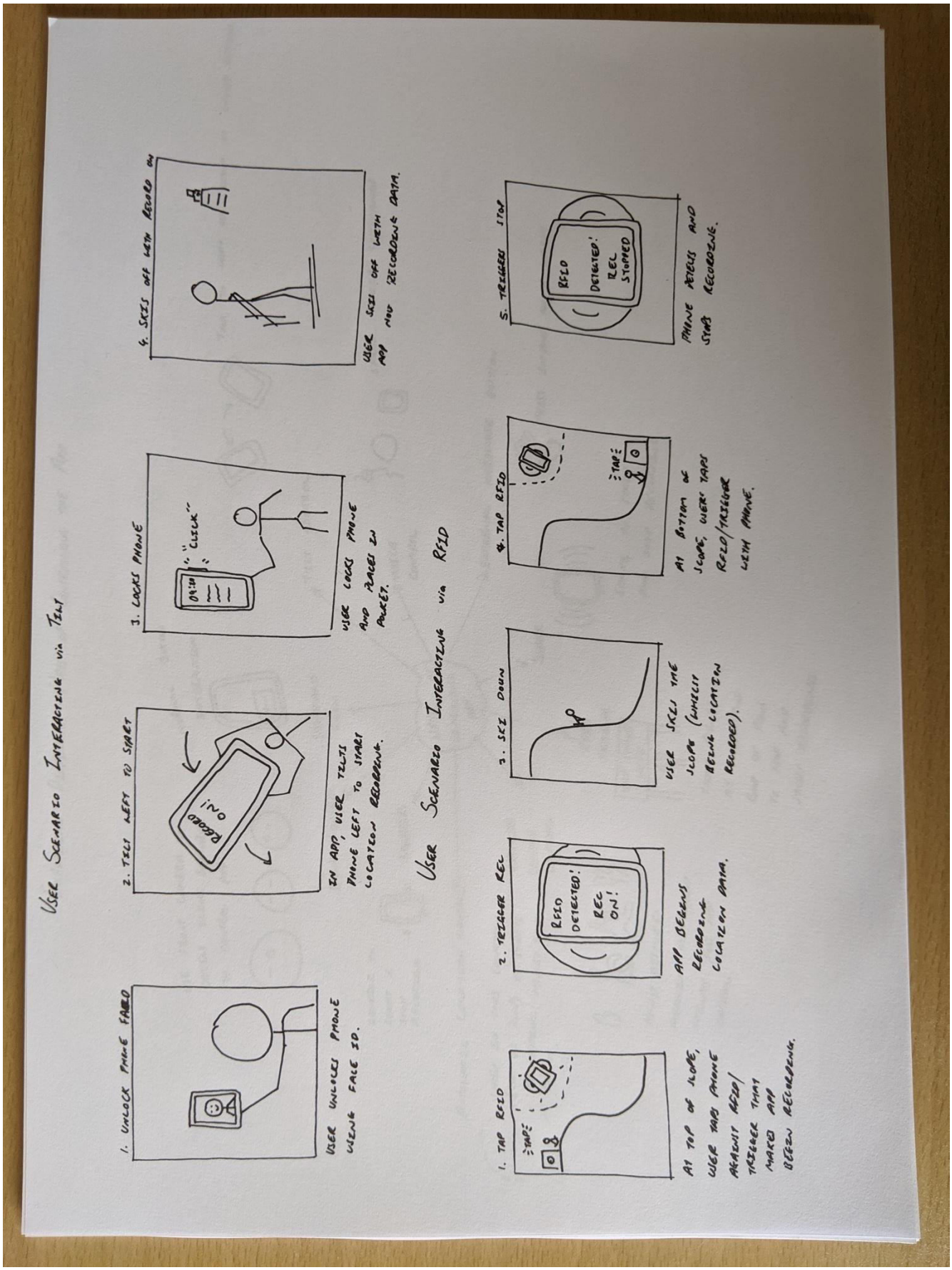
l. Swivel Mount Blown Up Sketch



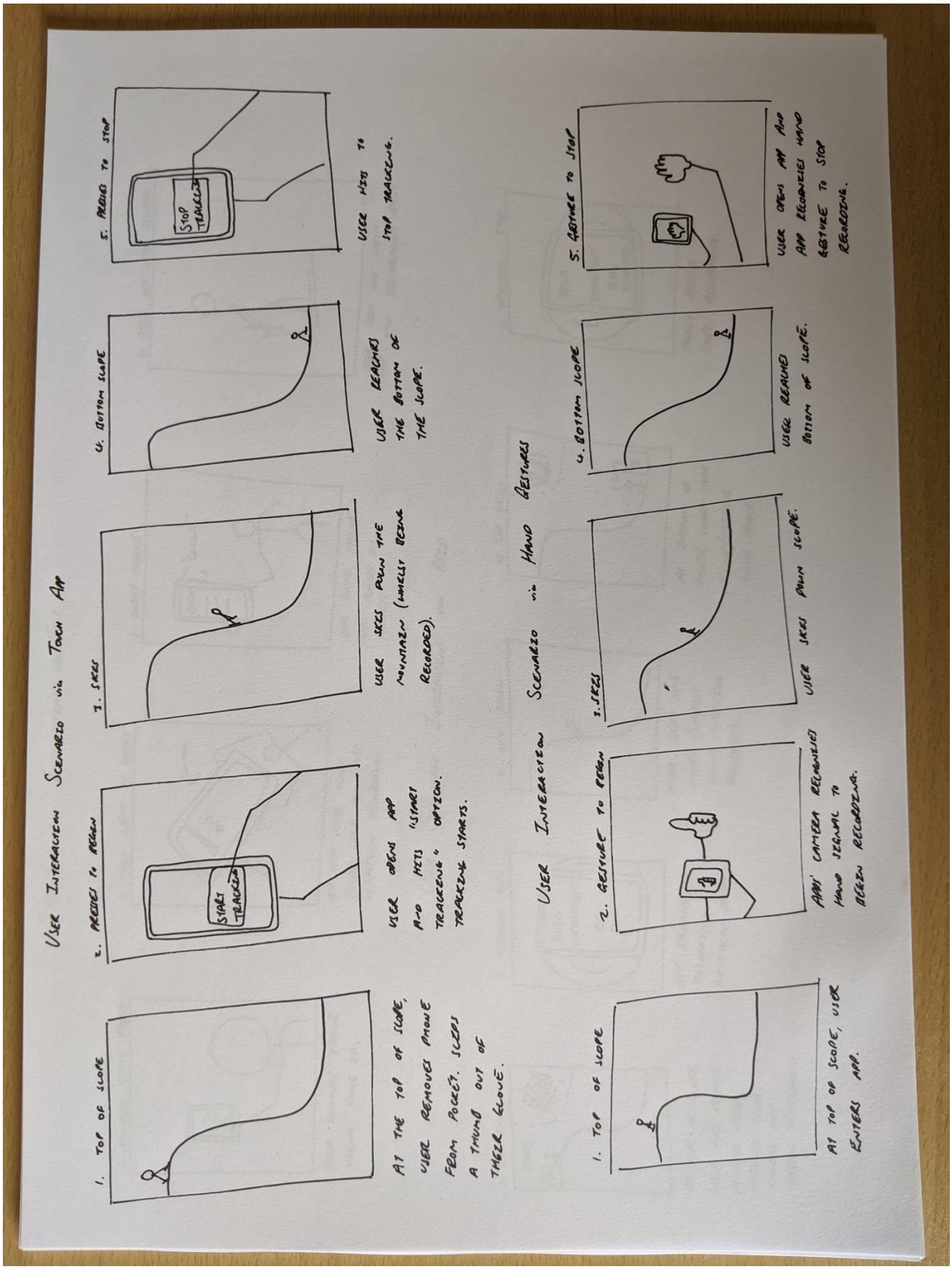
m. Mind-map exploring different ways of interacting with ski area app



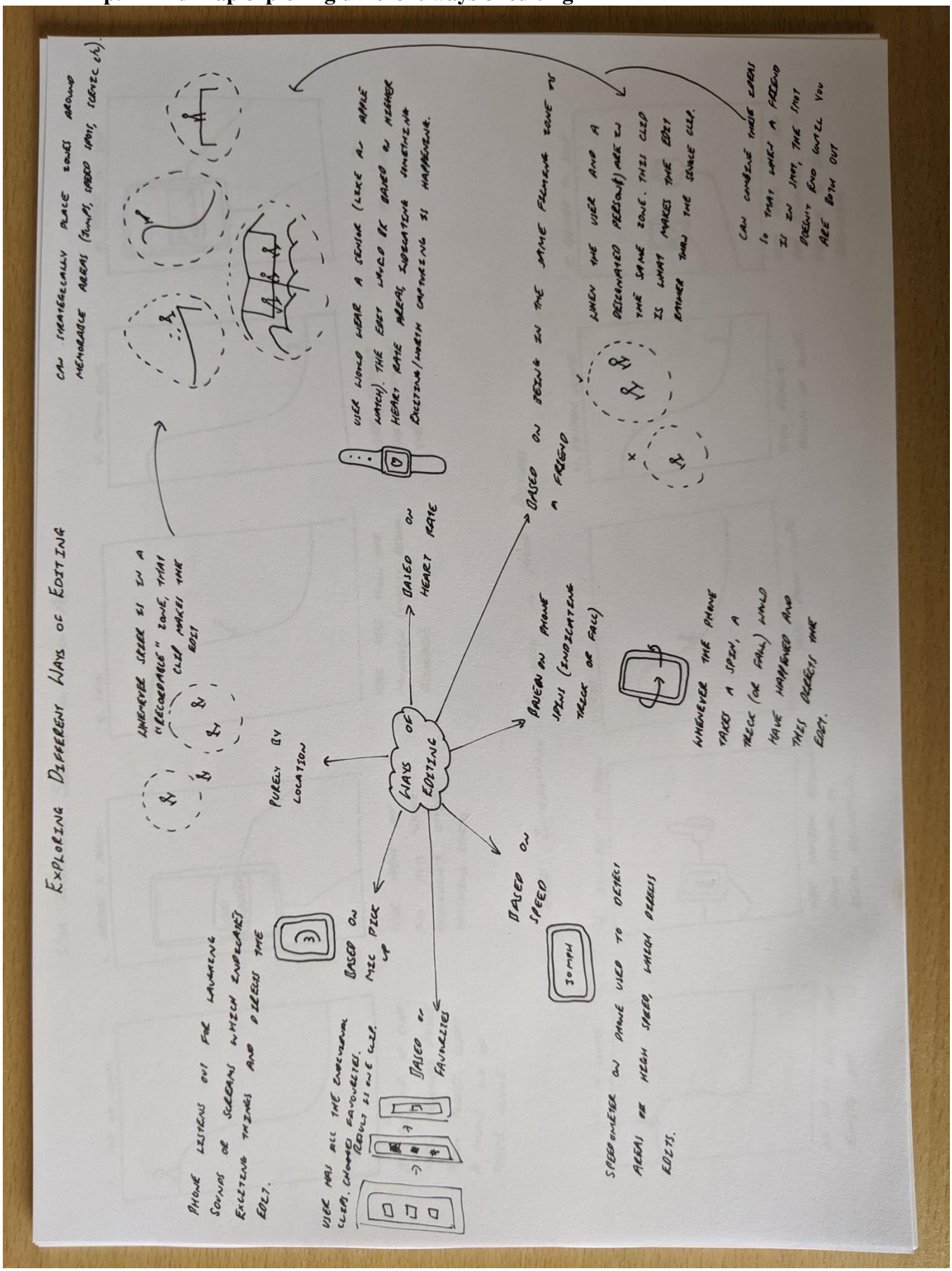
n. User Scenario of Interacting with app via Tilt



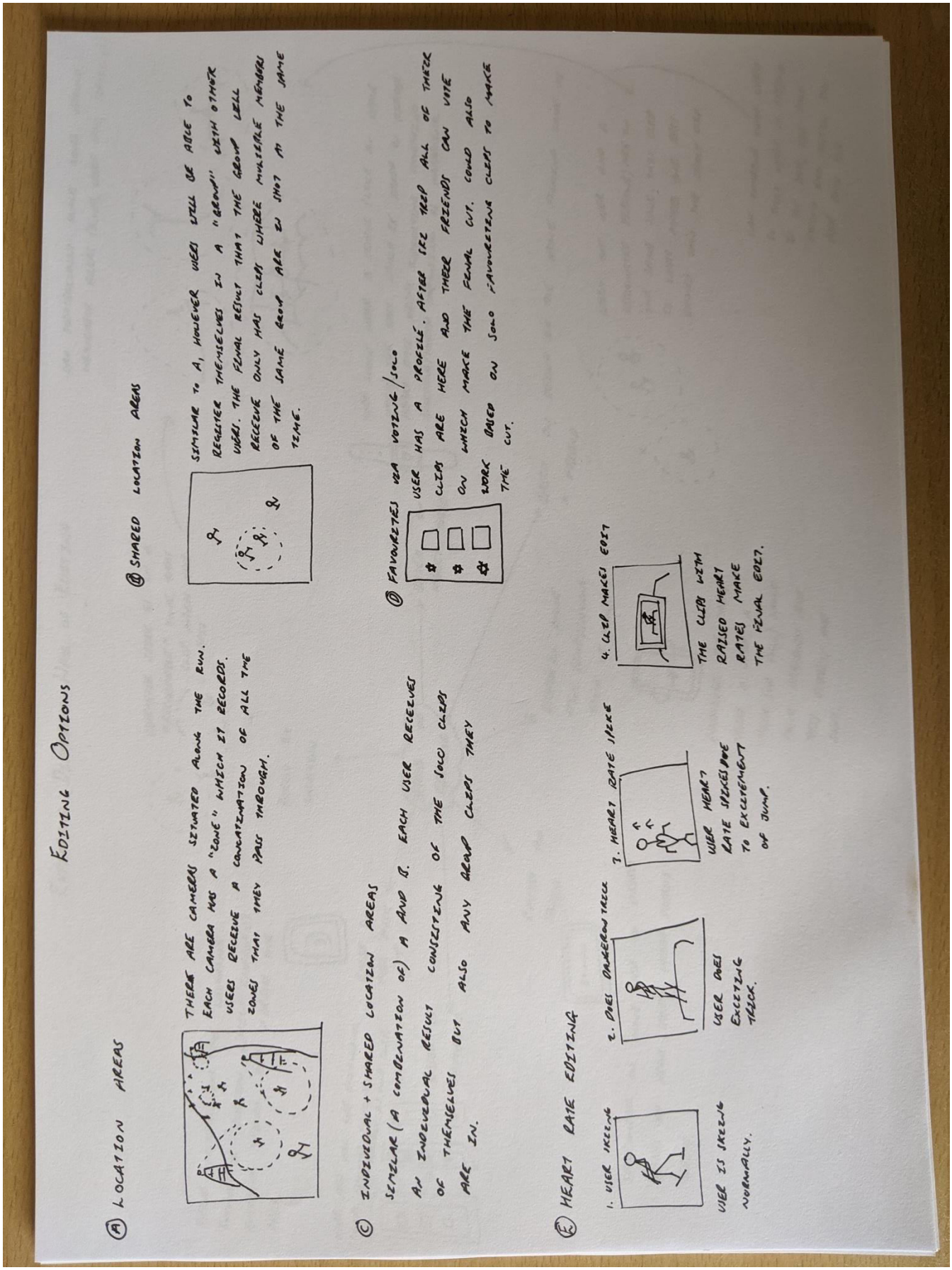
o. User Scenario of Interacting with app via Touch



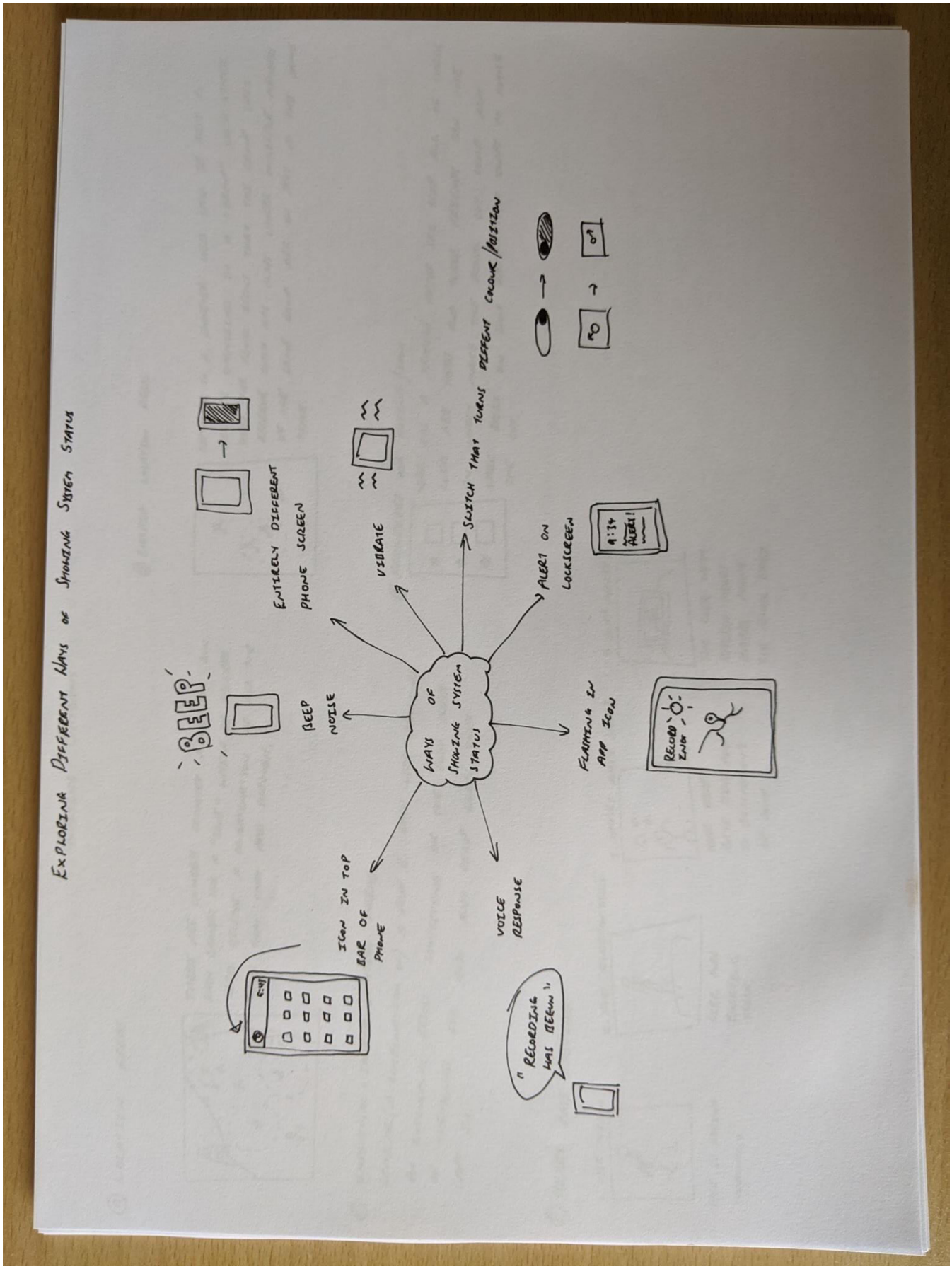
p. Mind-map exploring different ways of editing



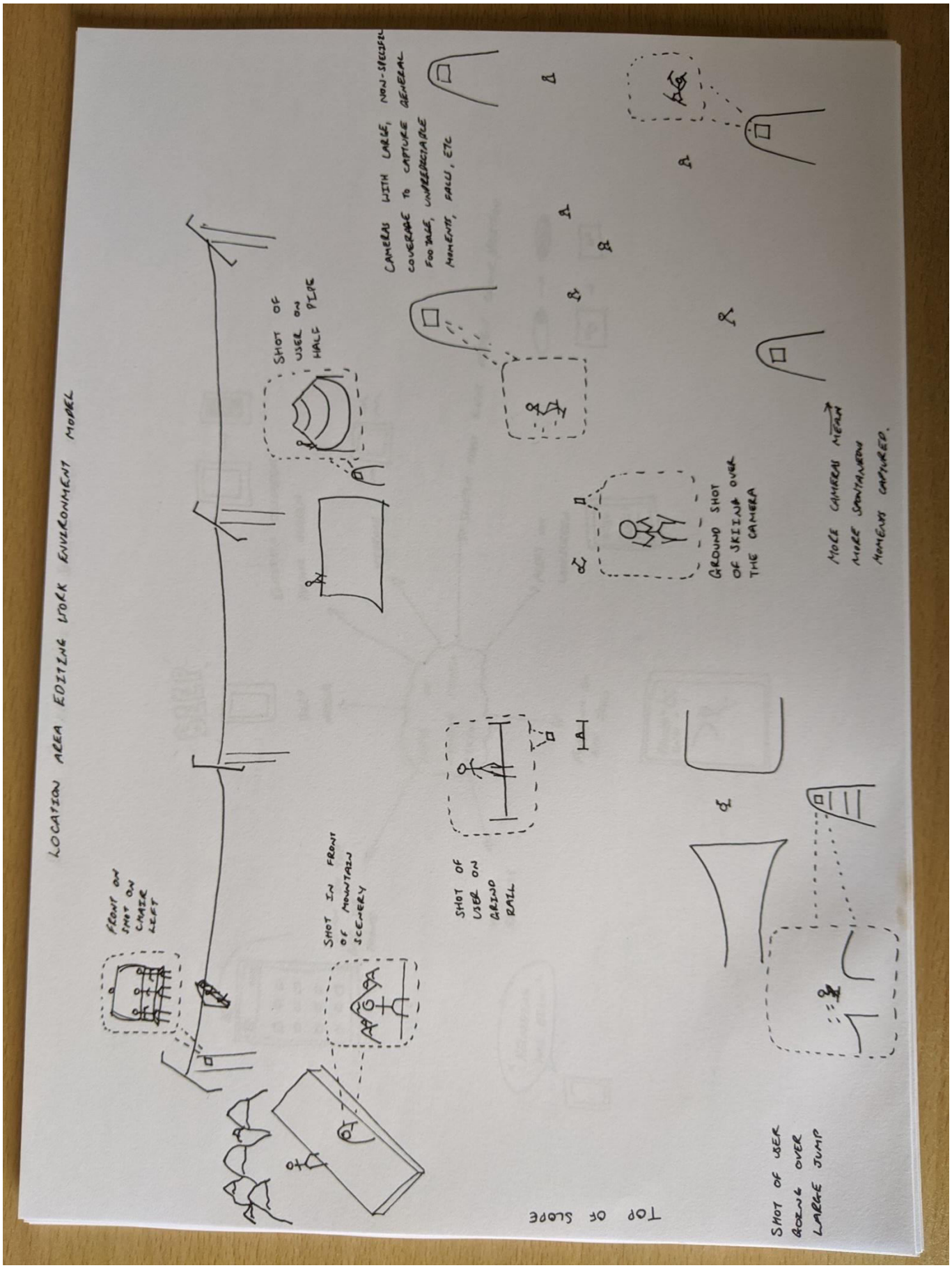
q. Exploring editing options



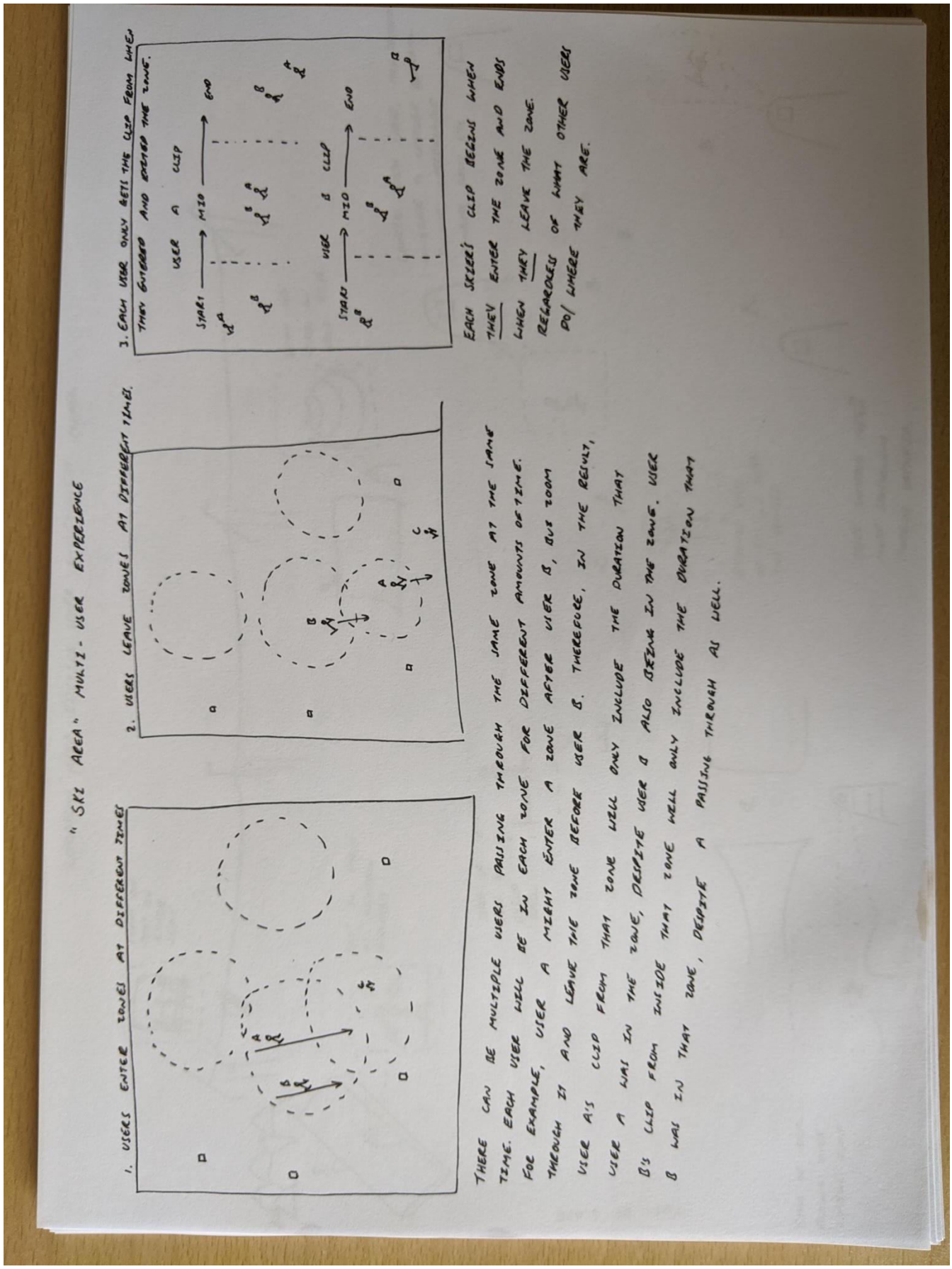
r. Mind-map exploring different ways of showing system status



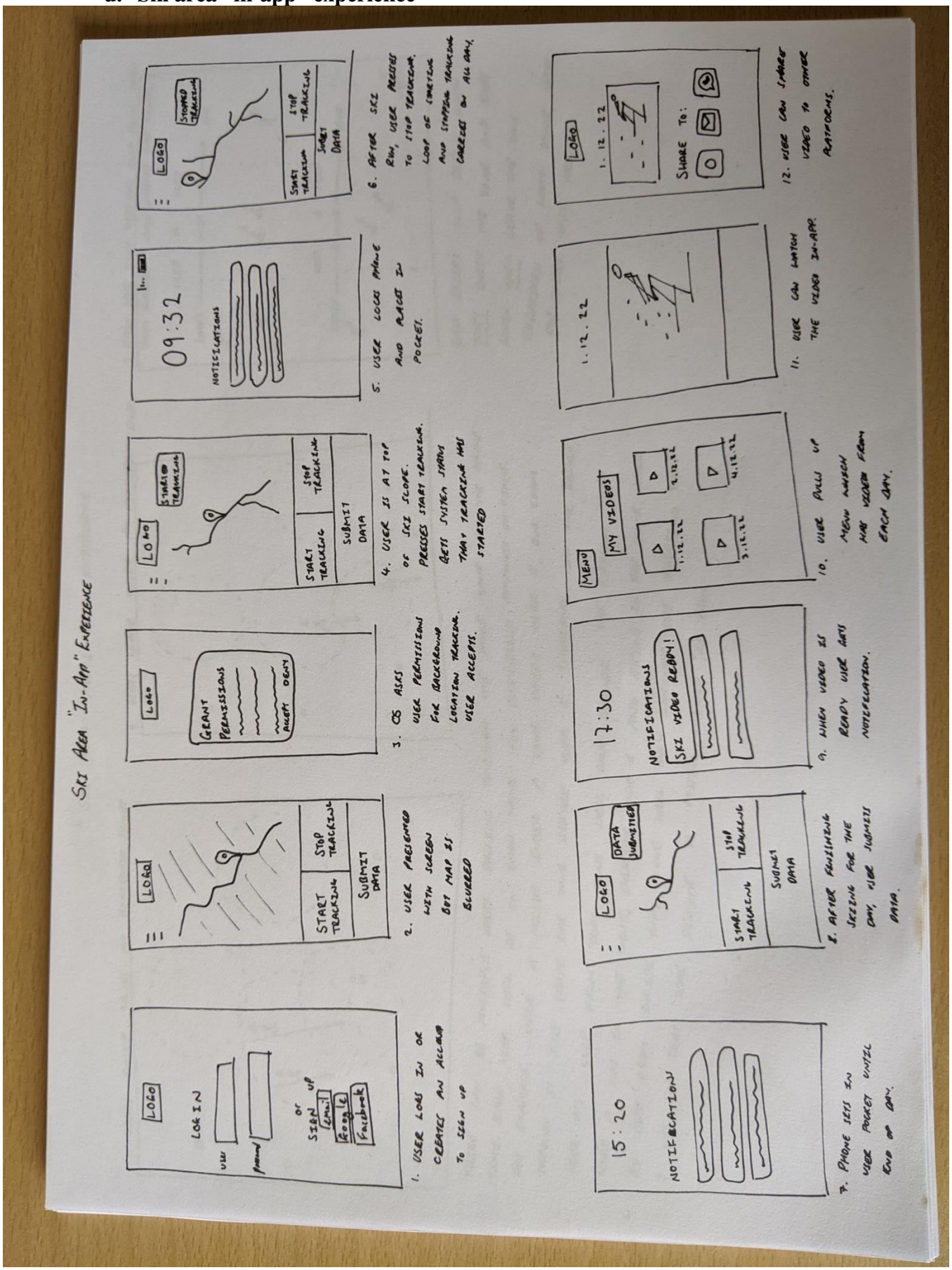
s. Ski area work environment model



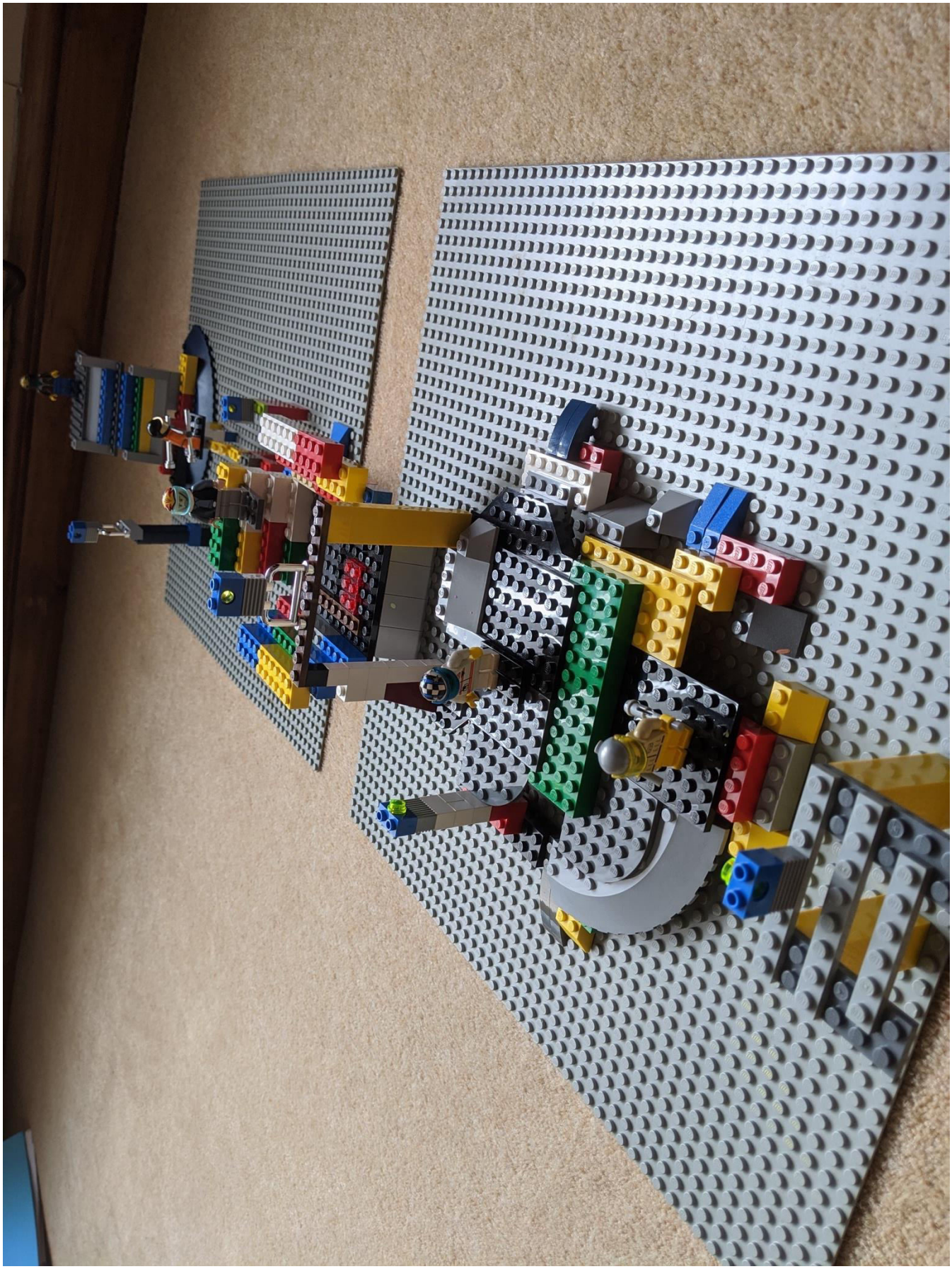
t. Exploring ski area multi-user experience

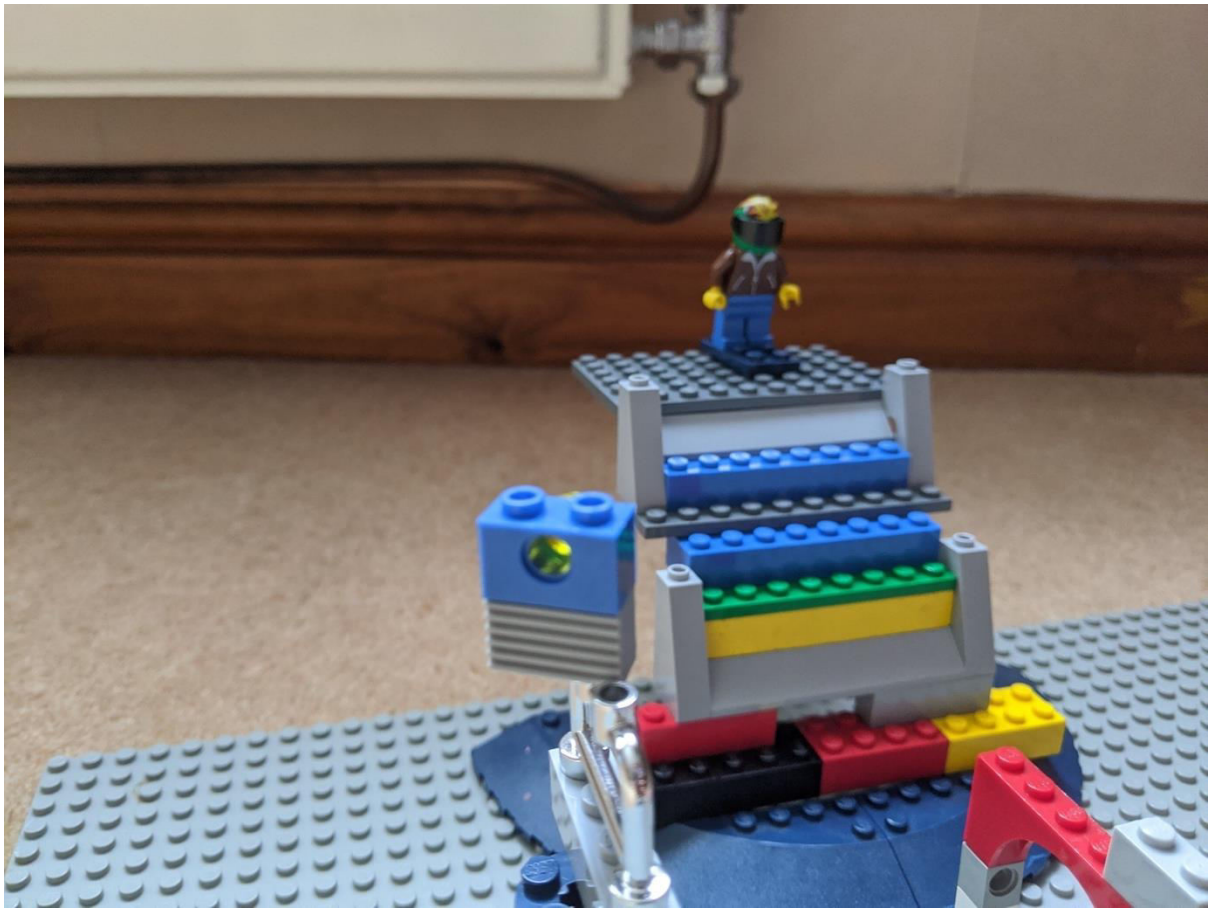


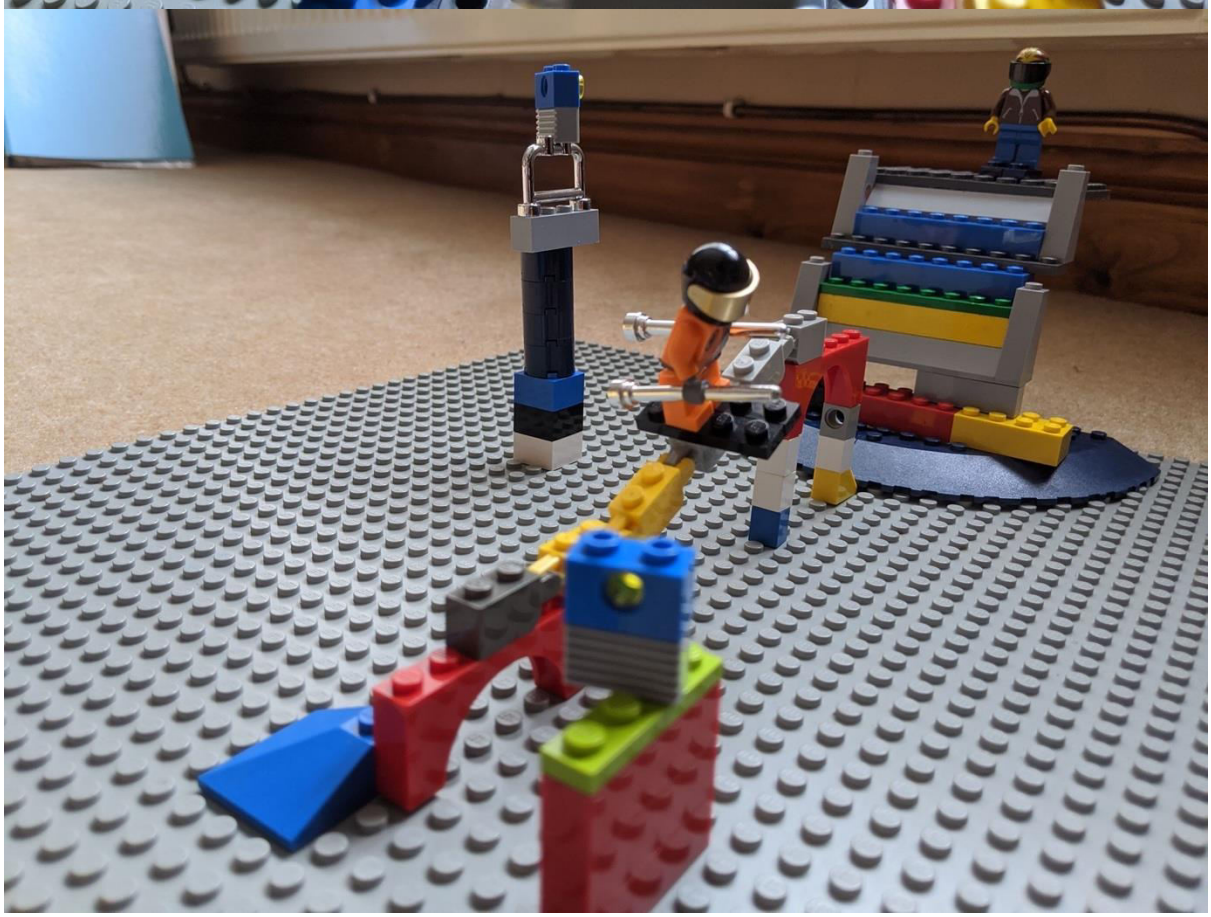
u. Ski area “in-app” experience



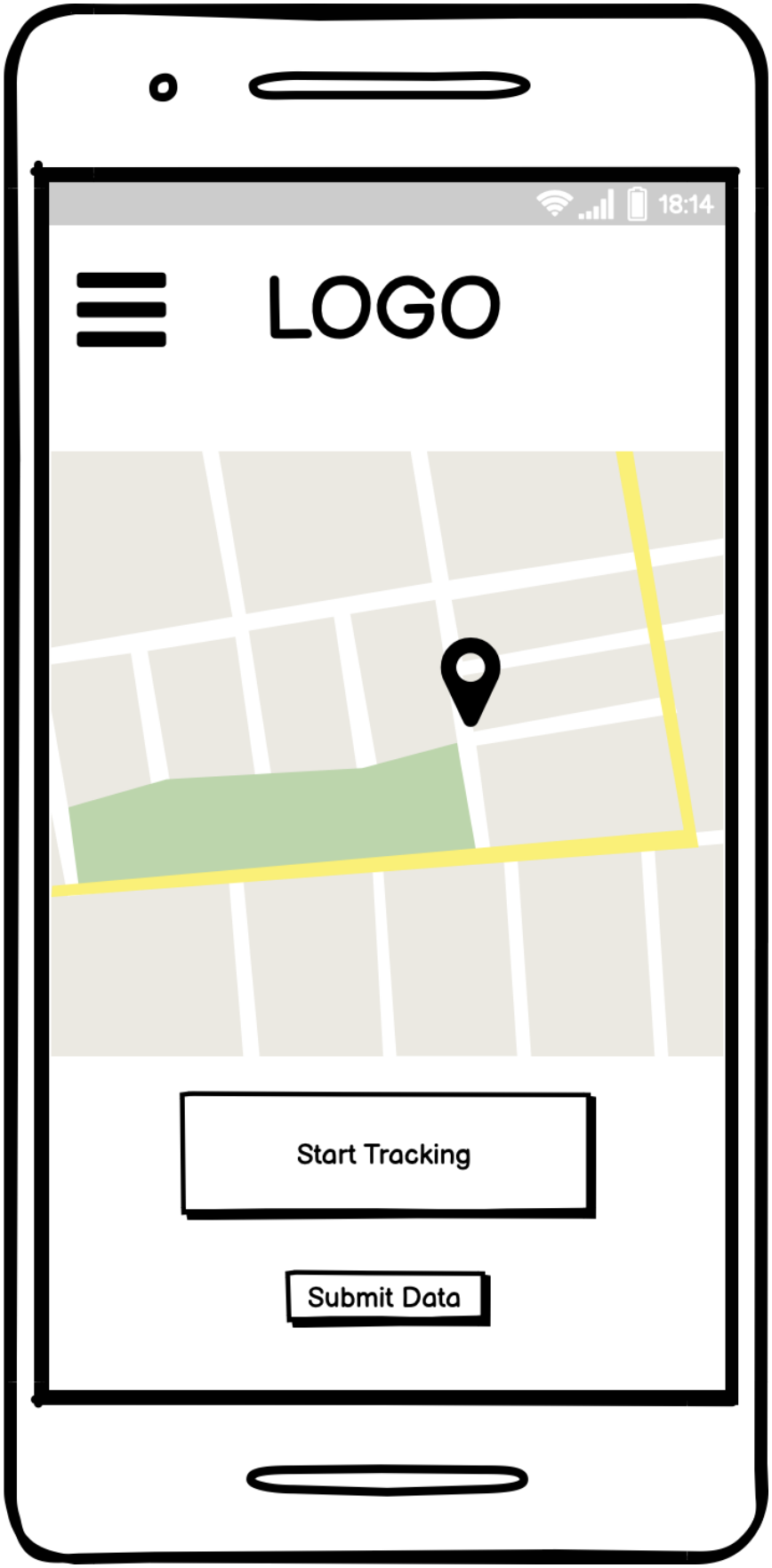
v. Ski Area physical Lego model







w. Wireframe Versions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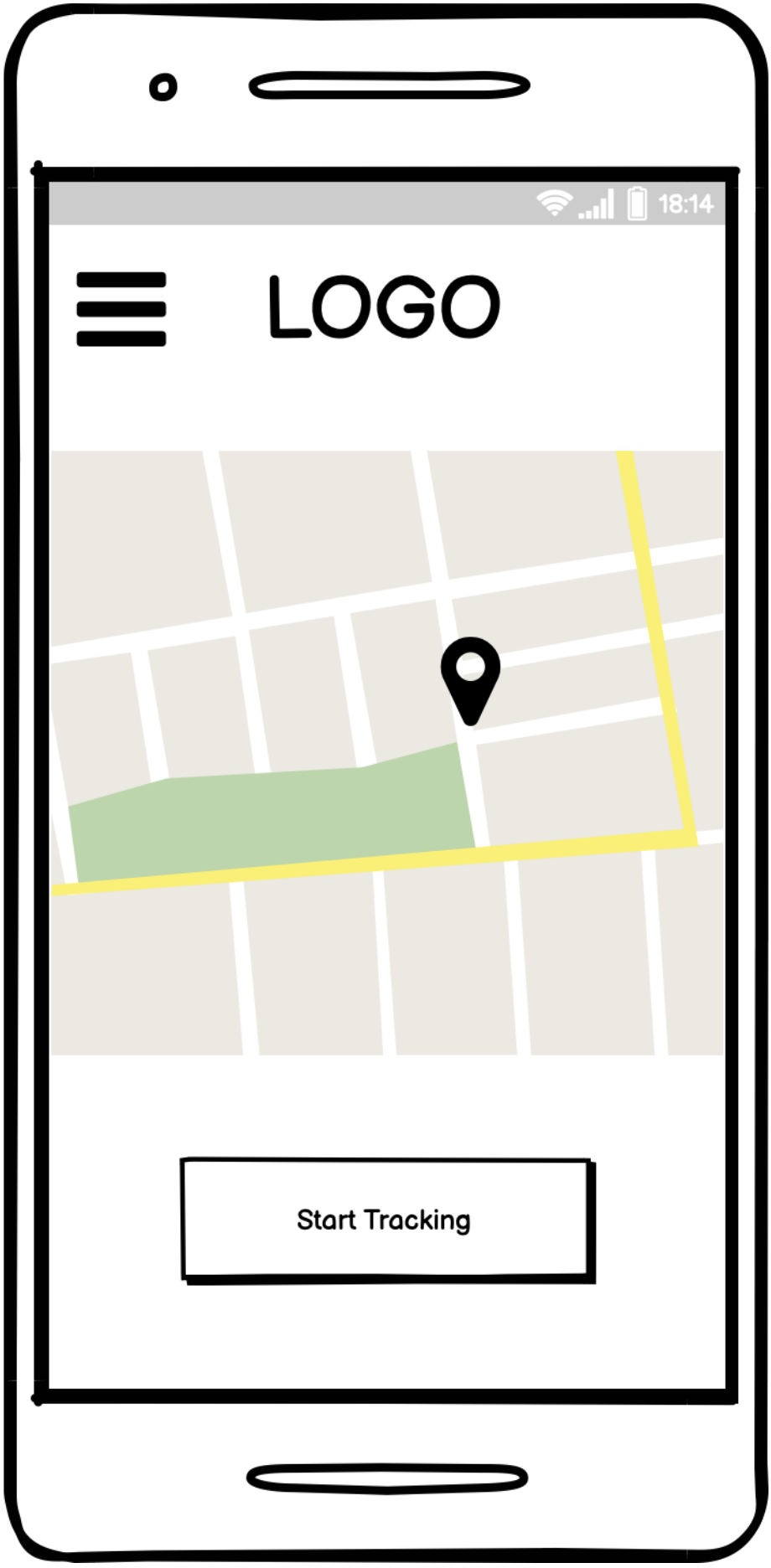
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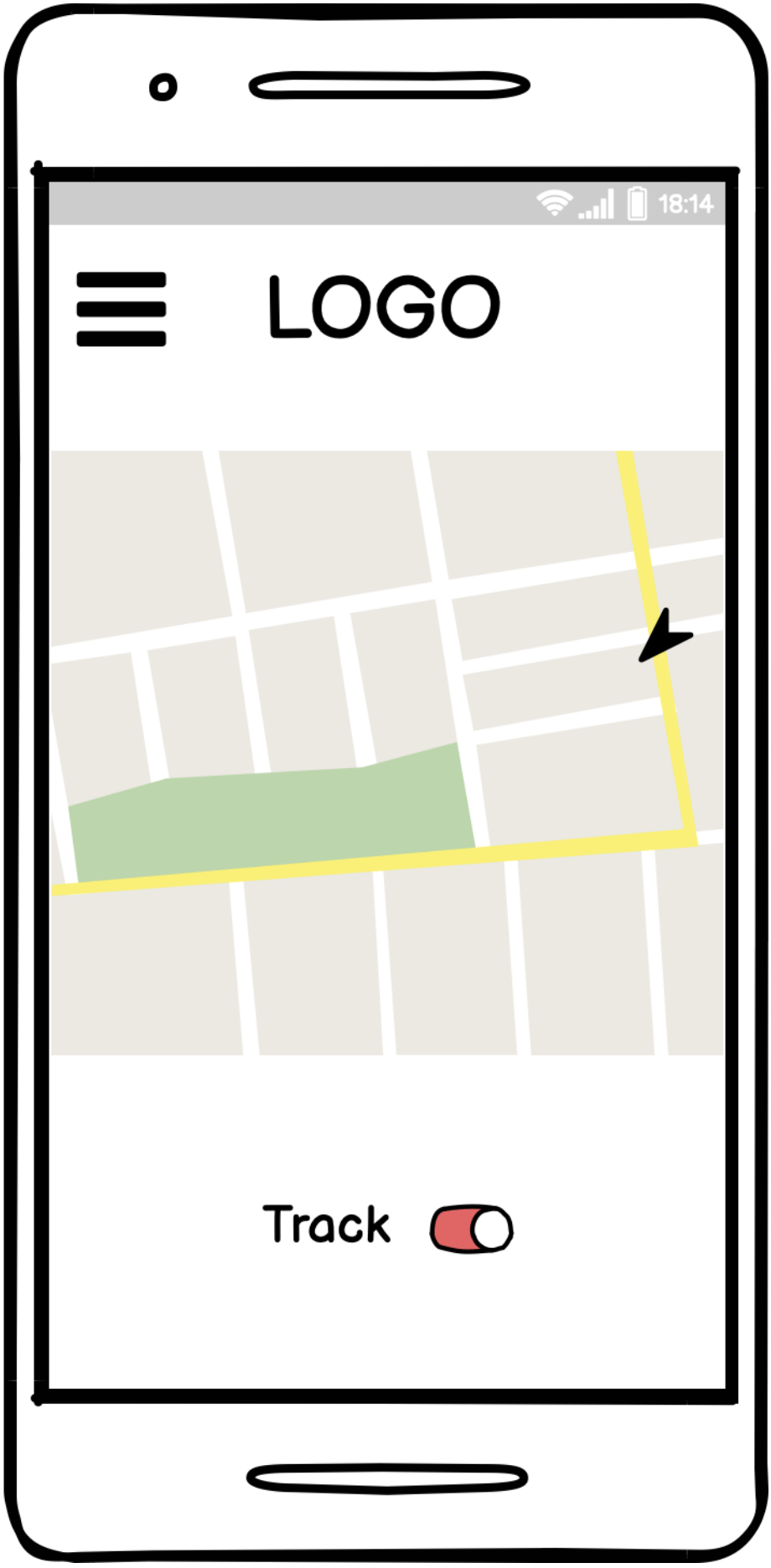
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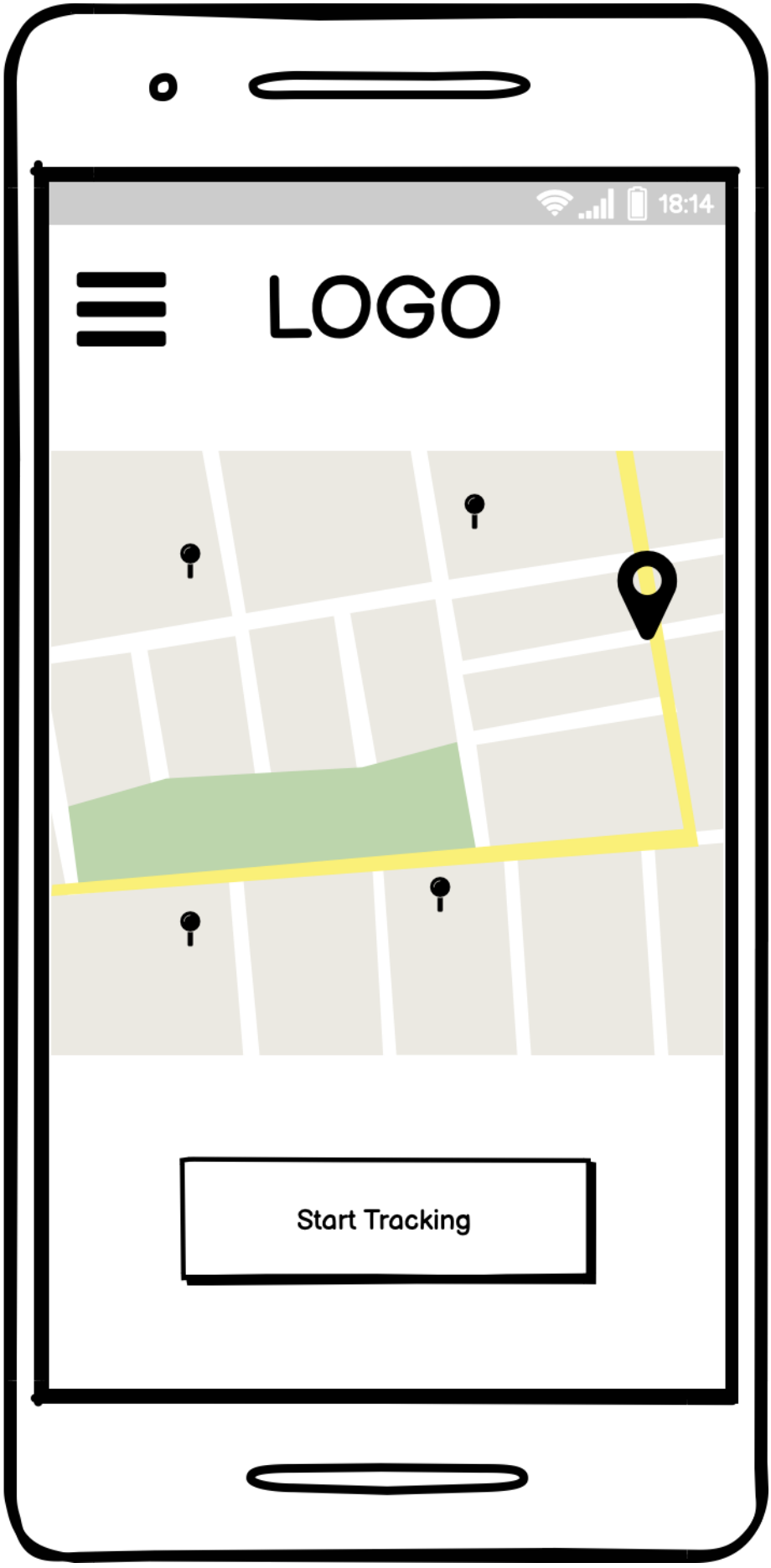
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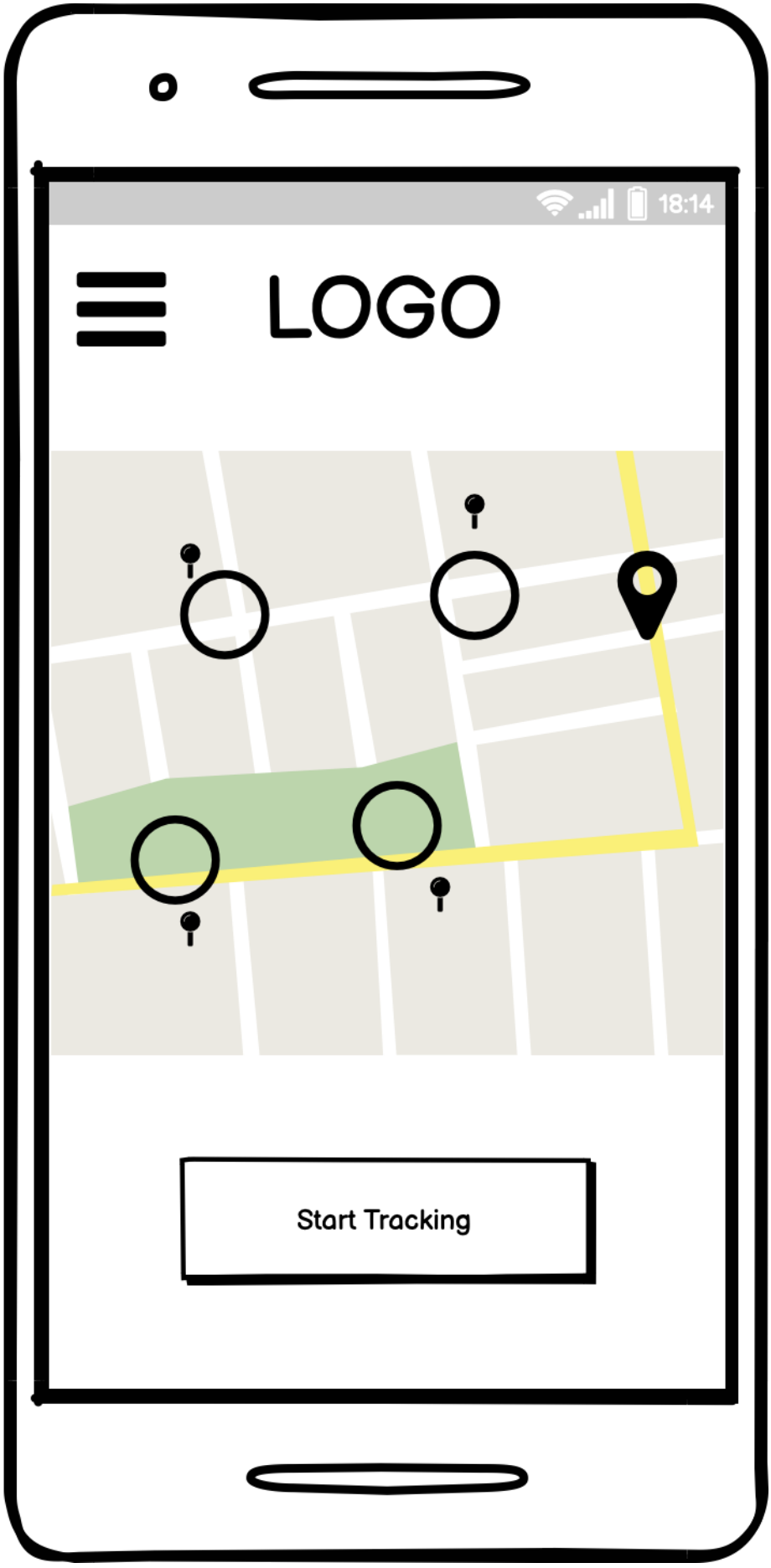
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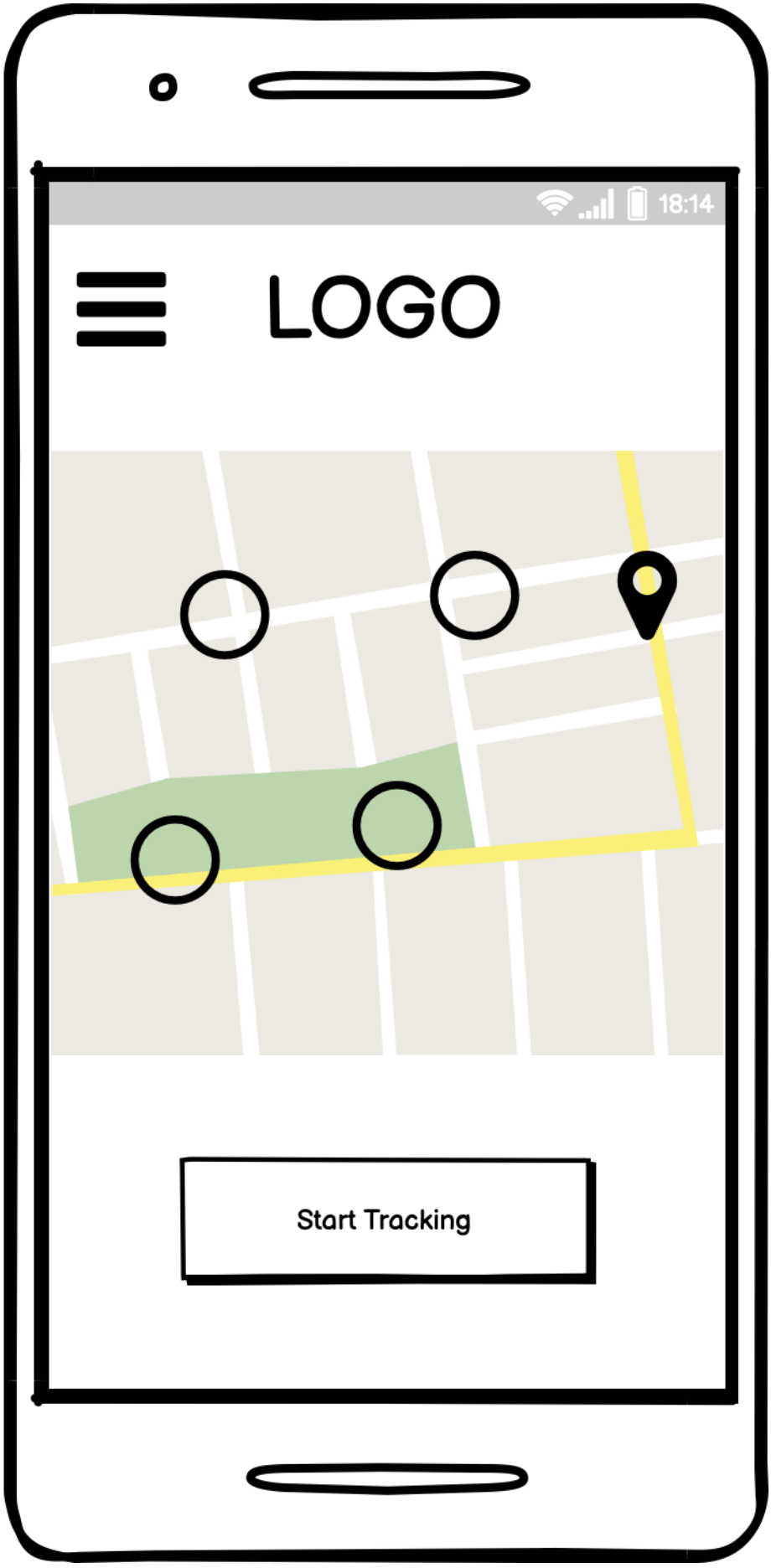
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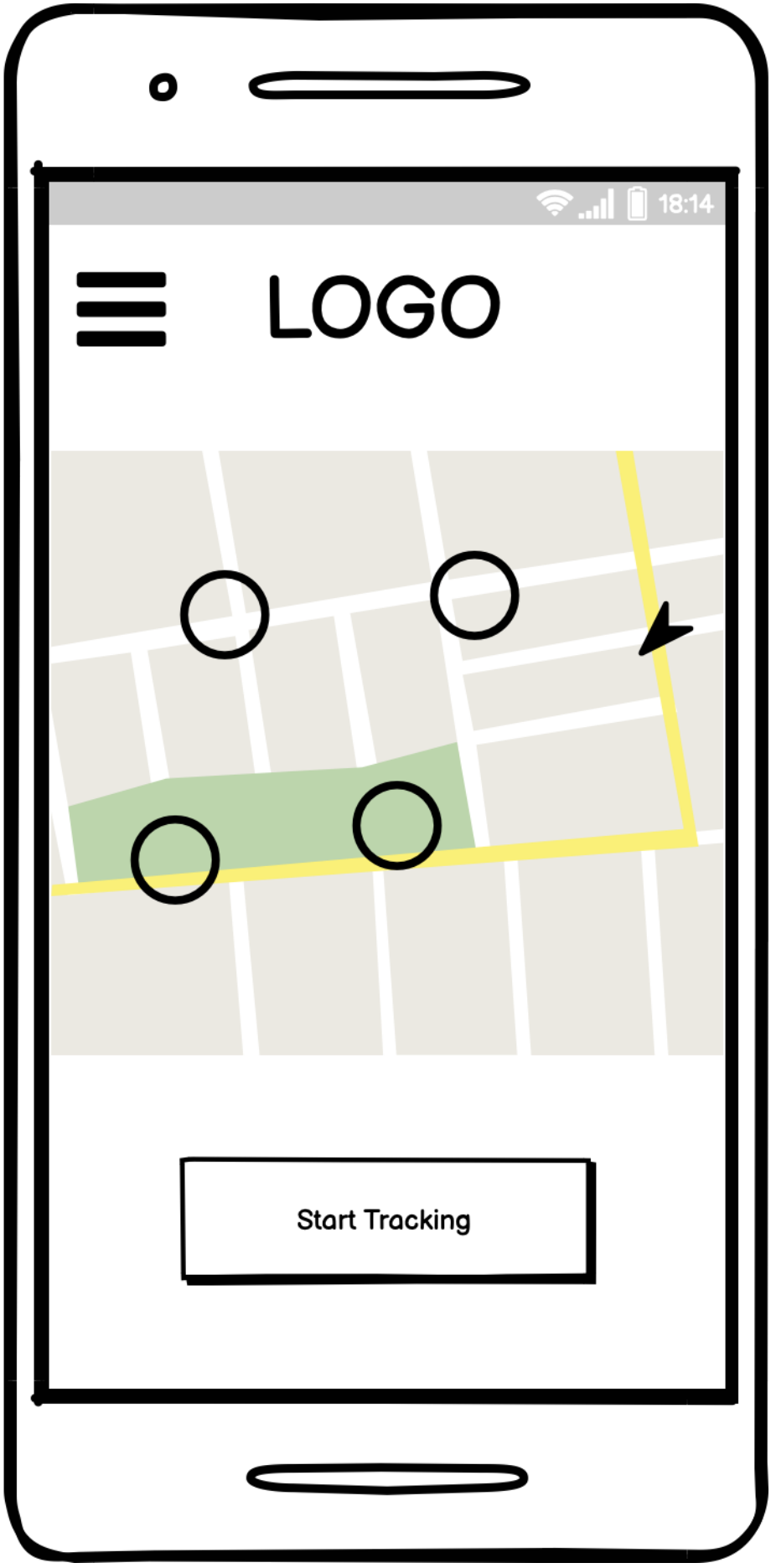
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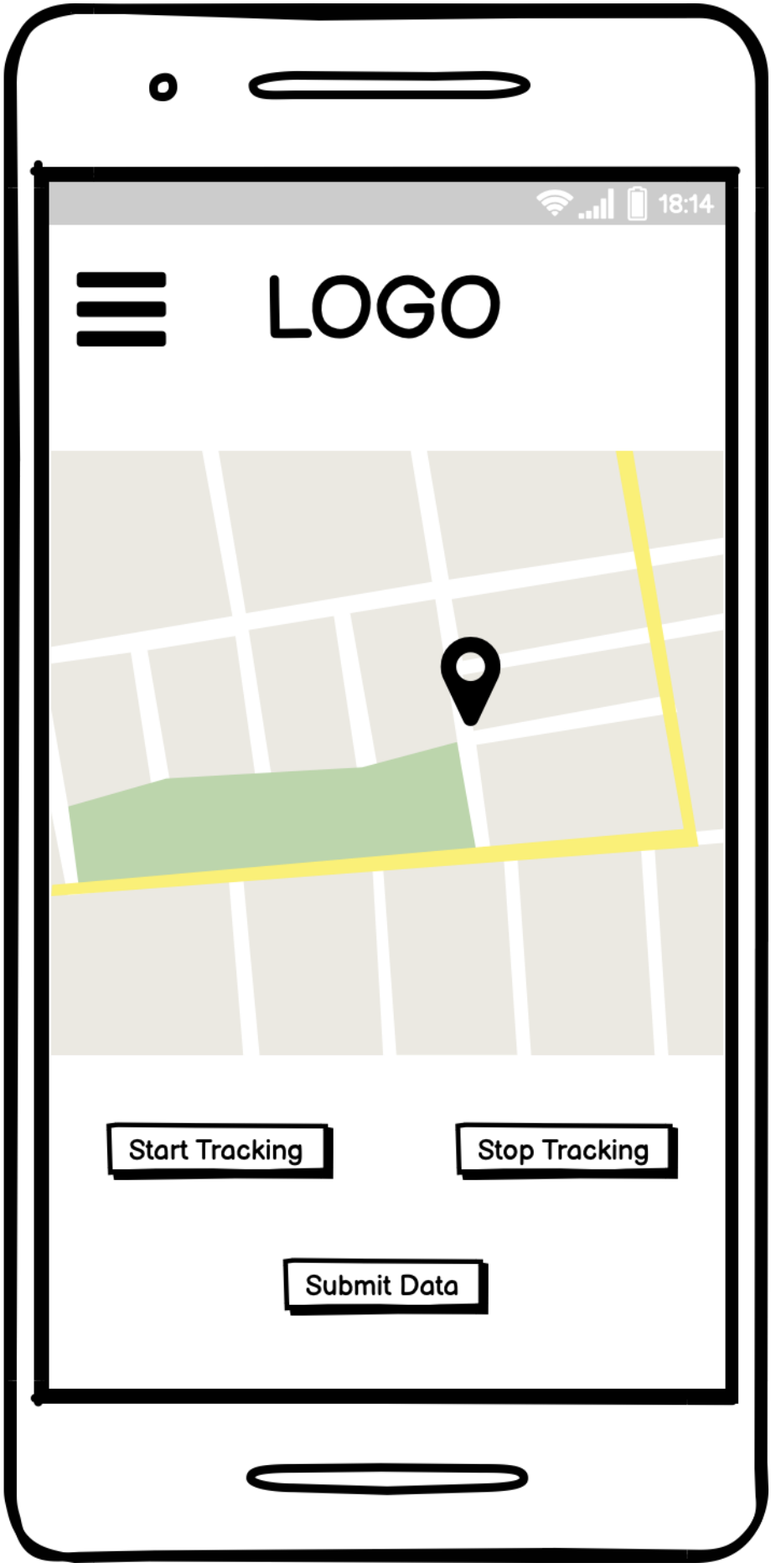
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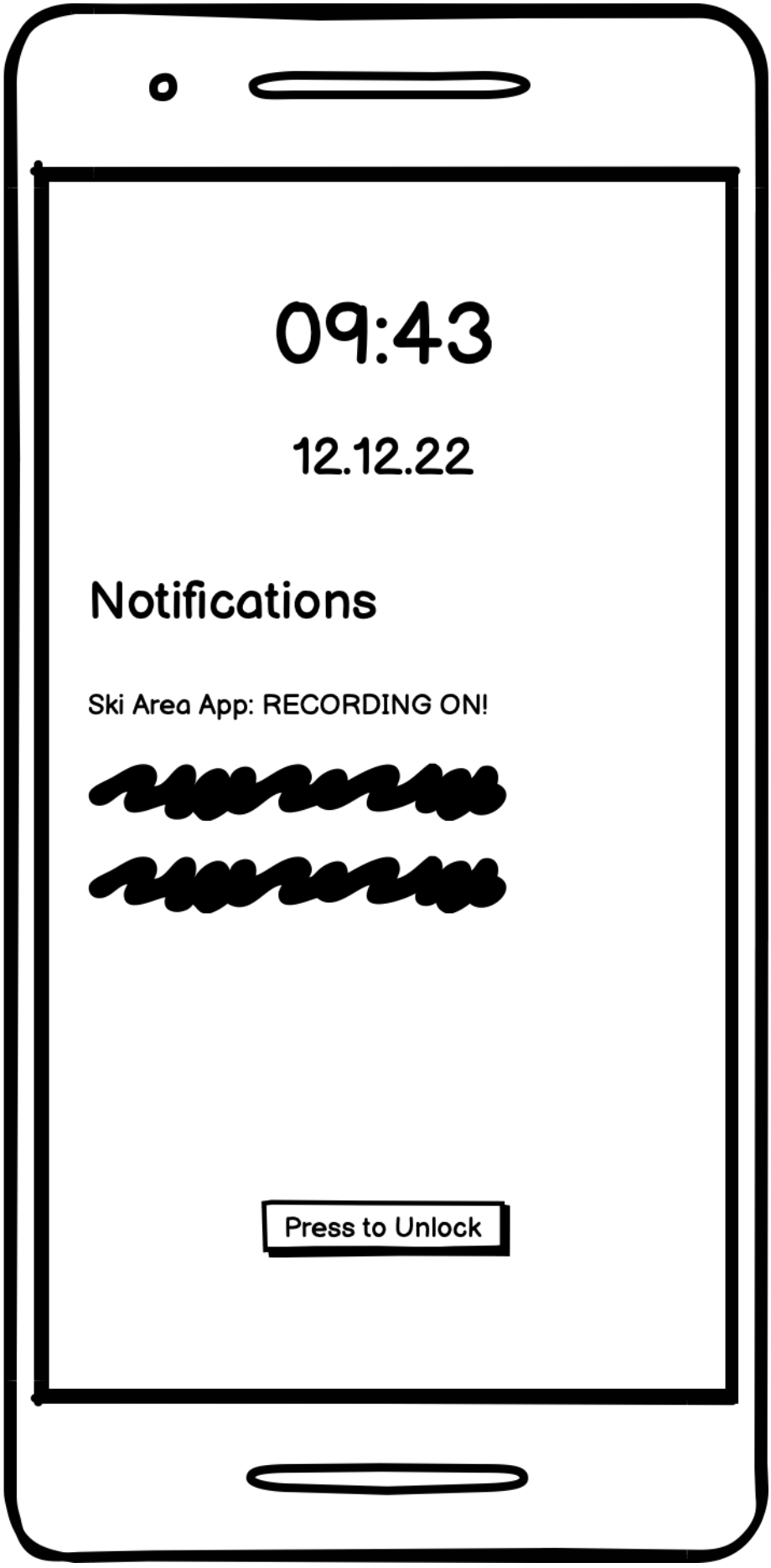
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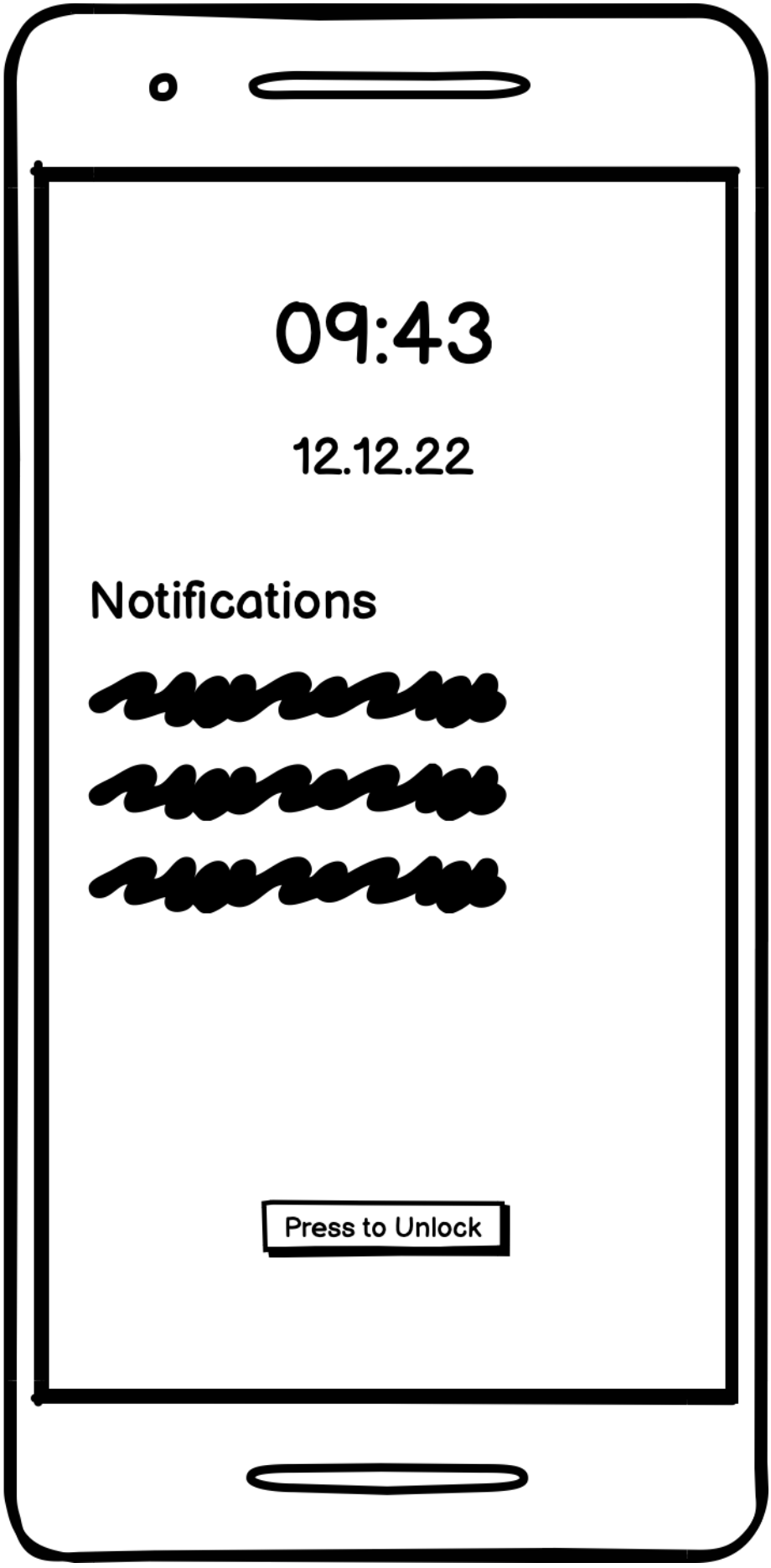
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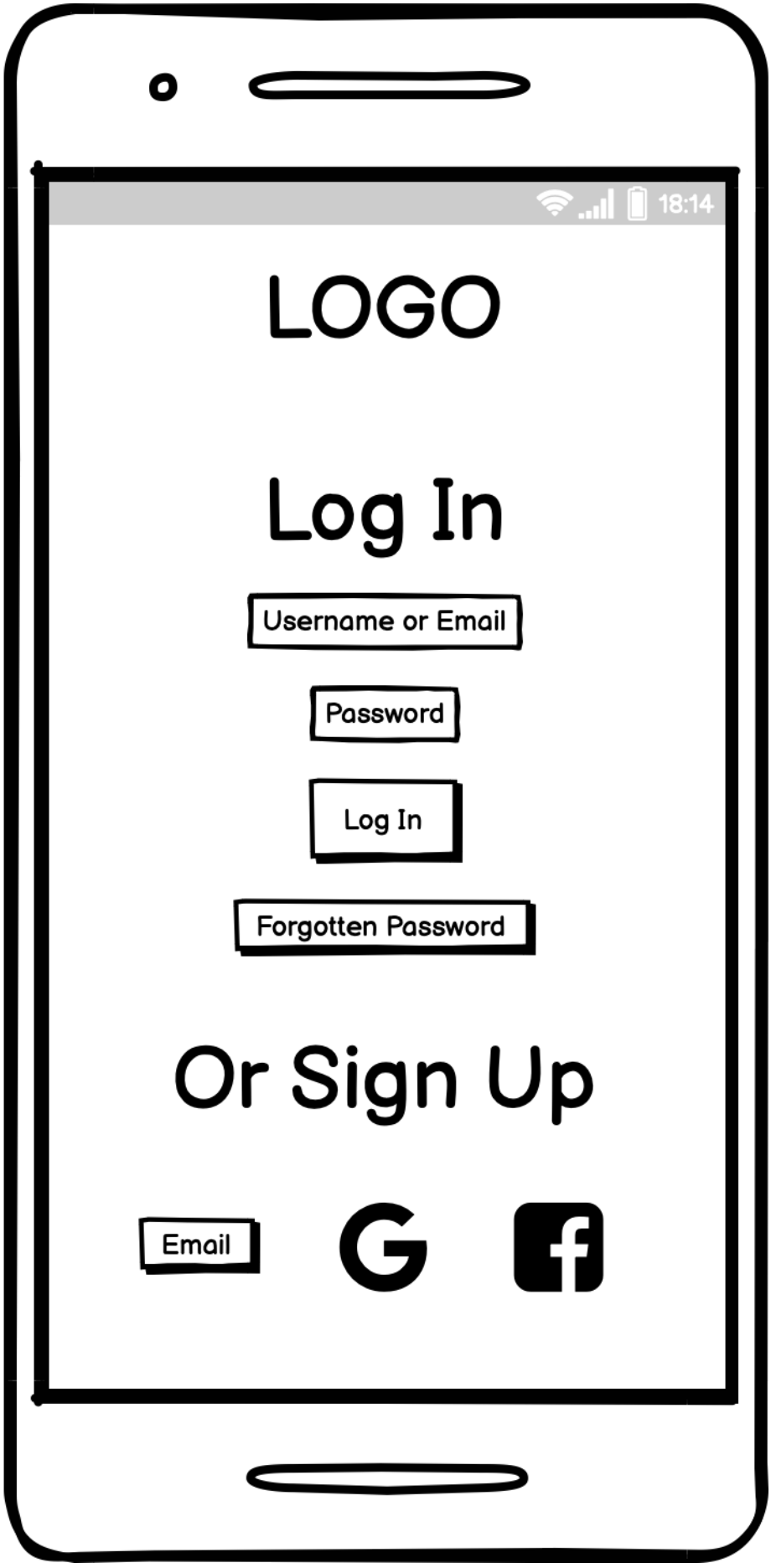
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Or Sign Up
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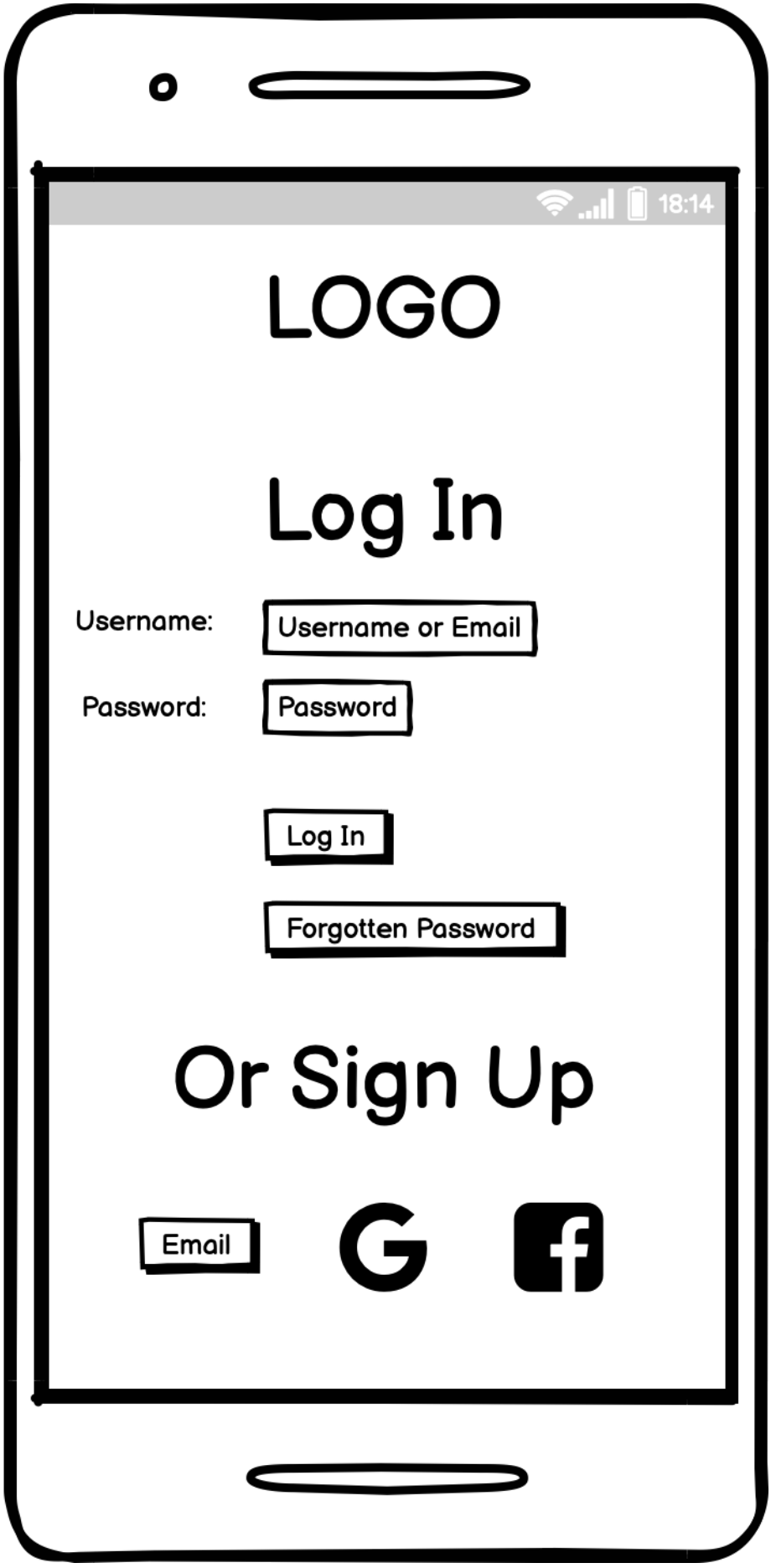
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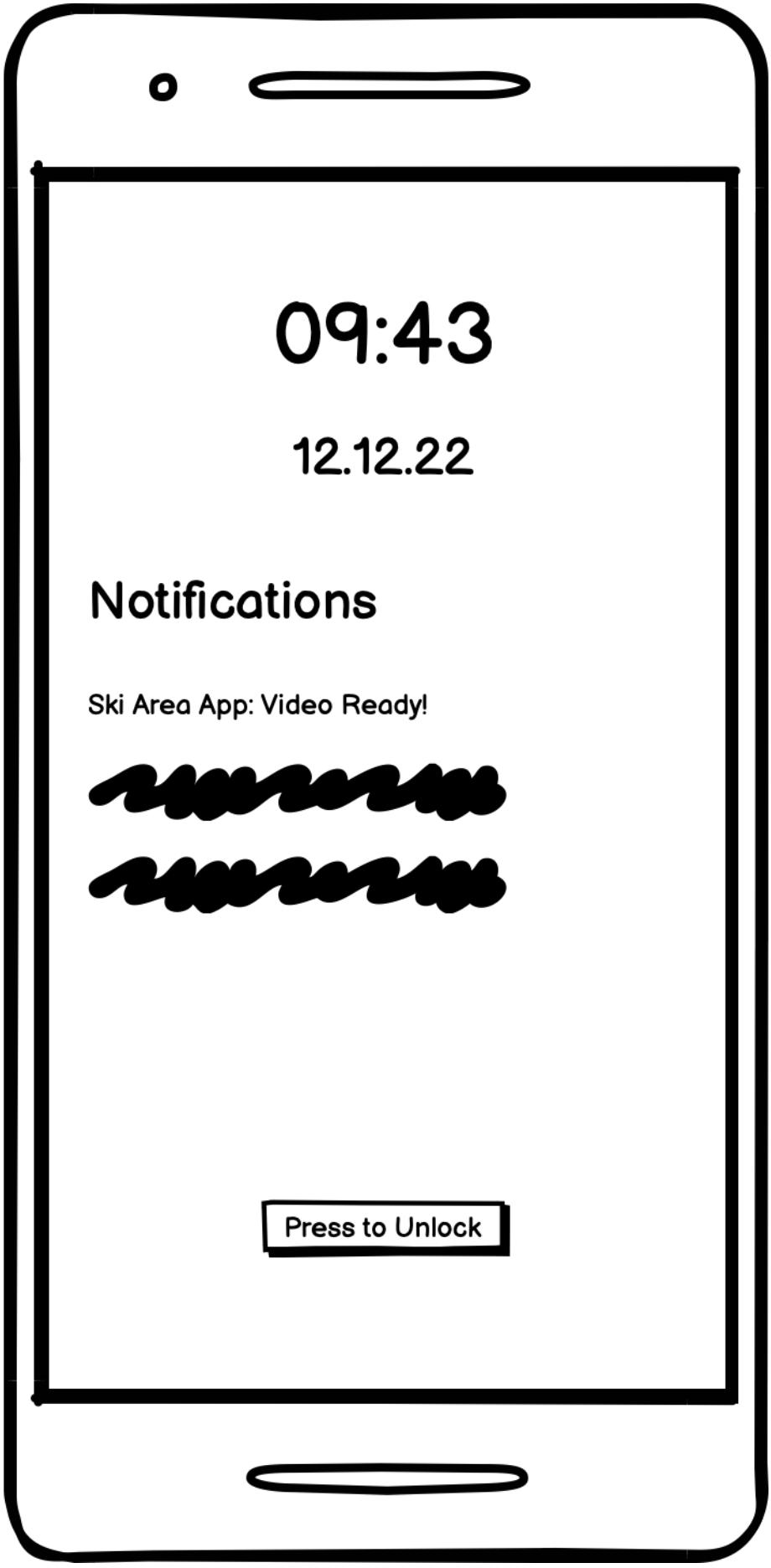
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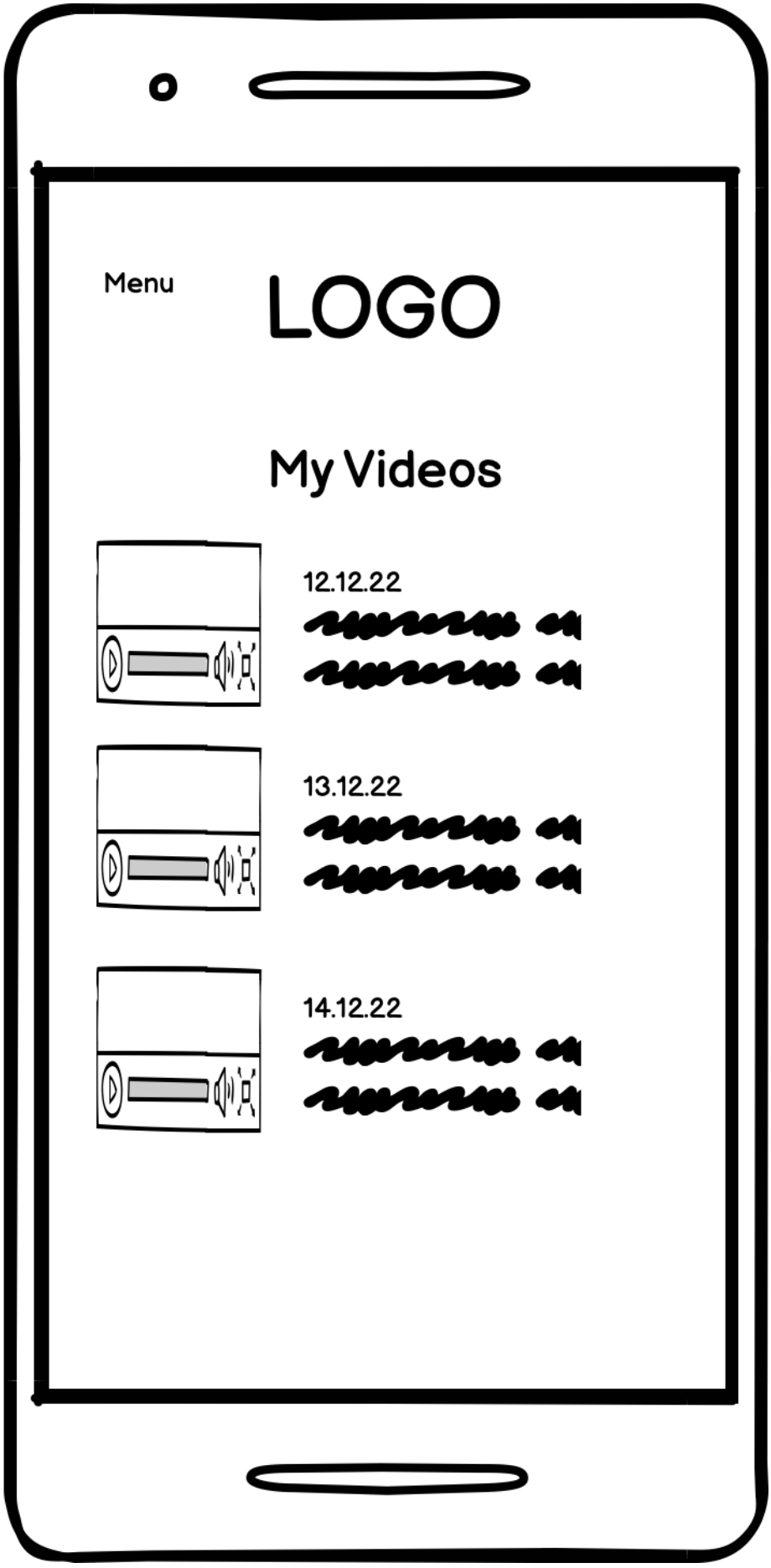
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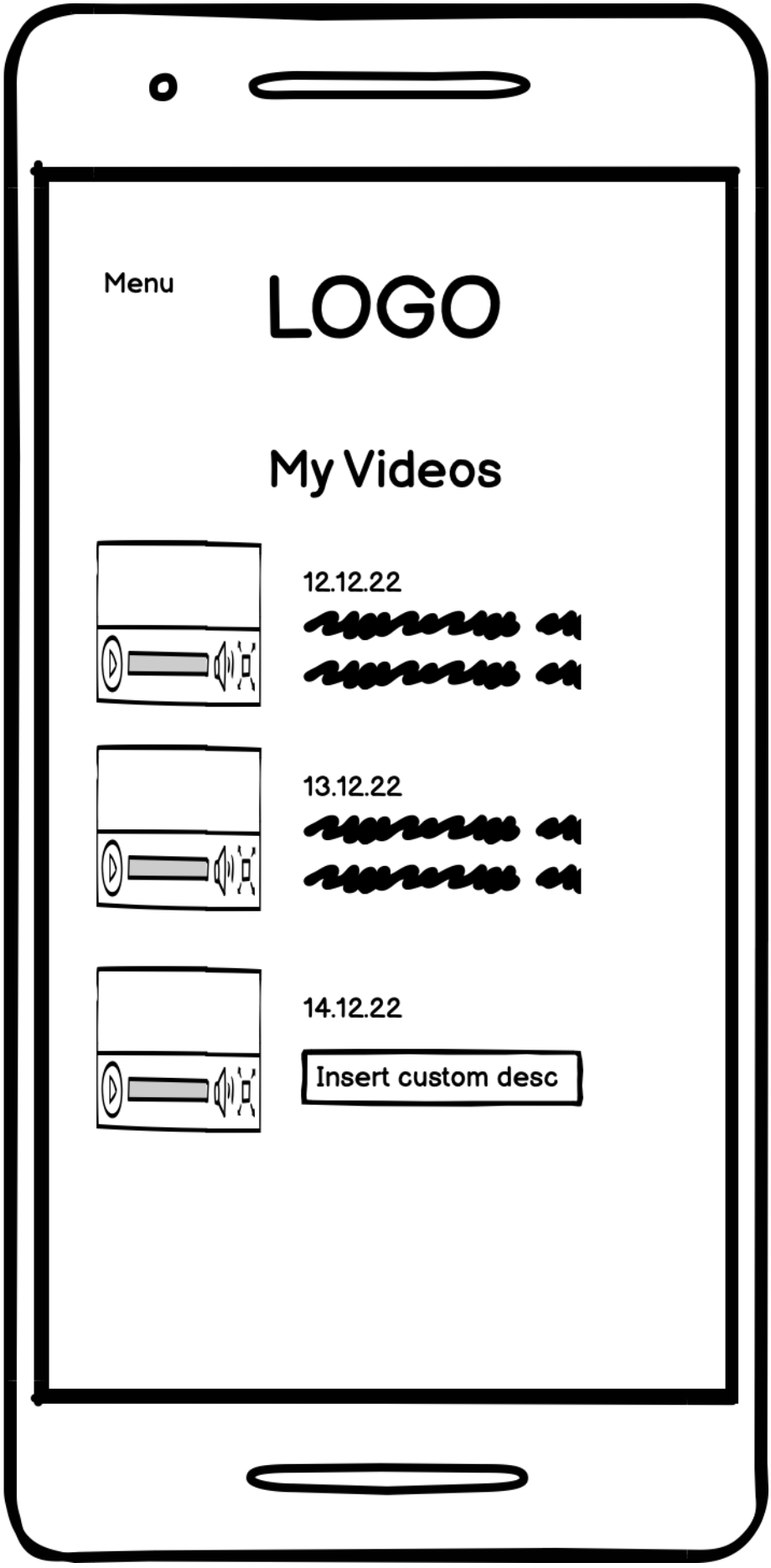
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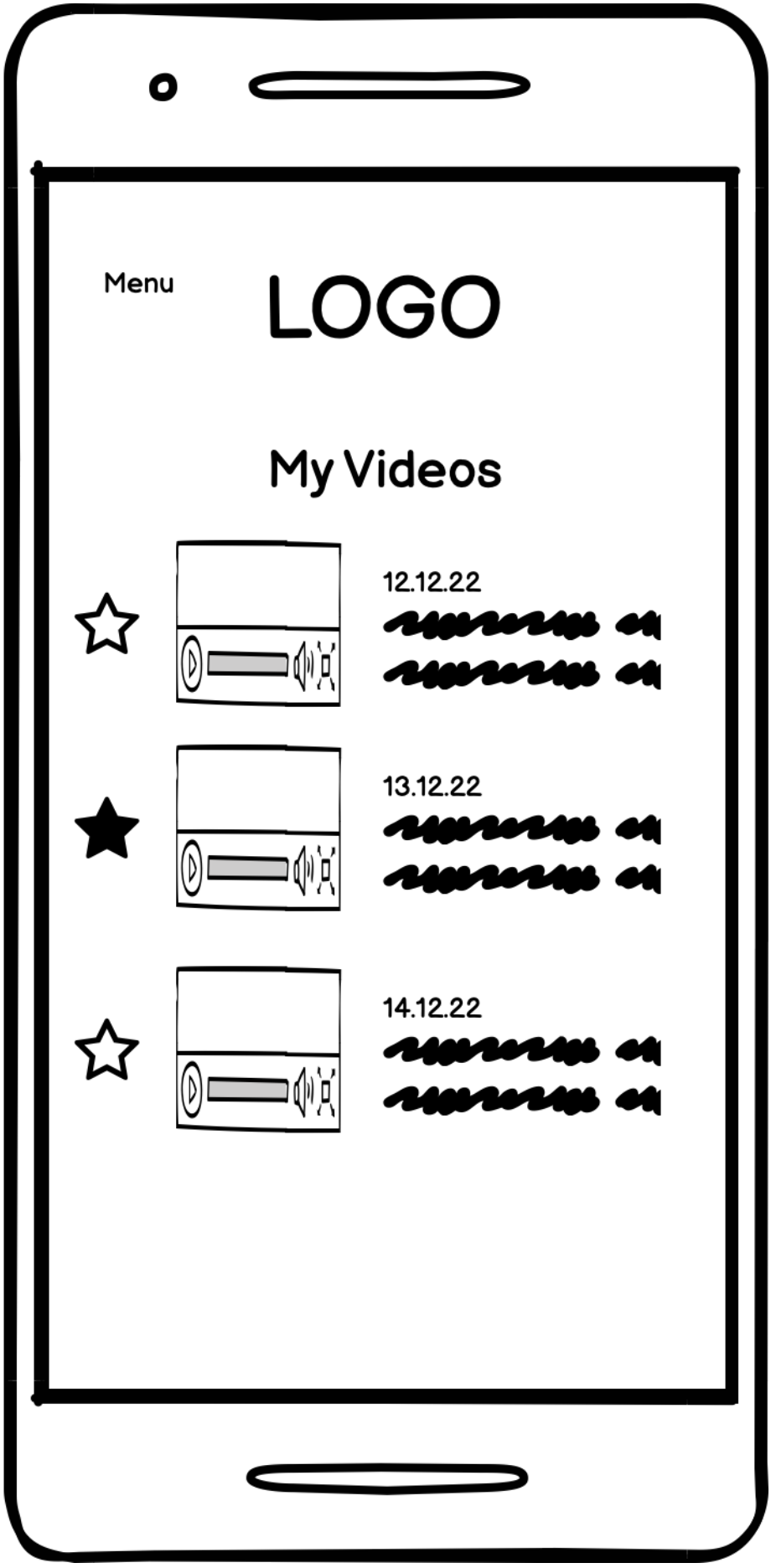
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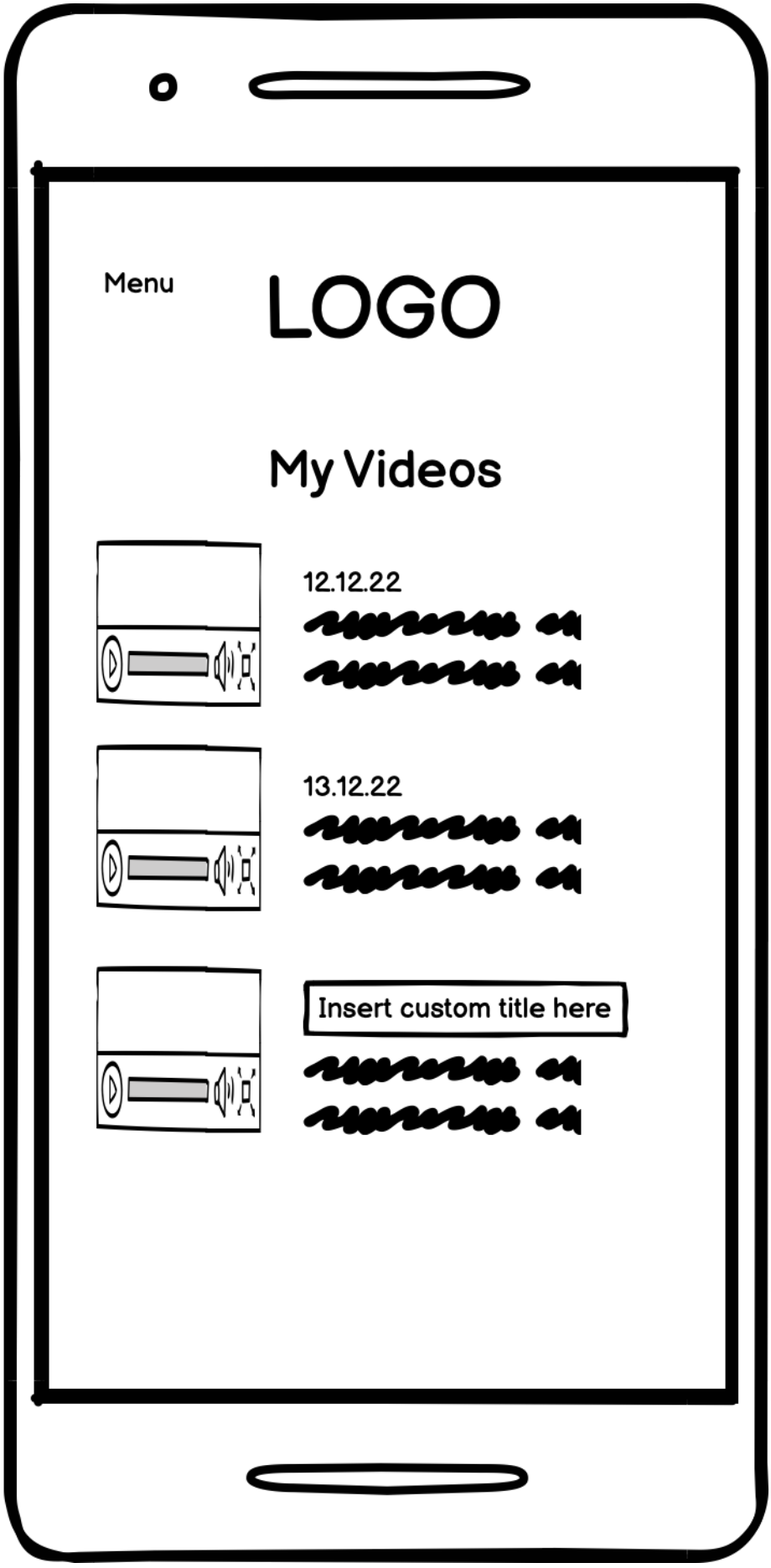
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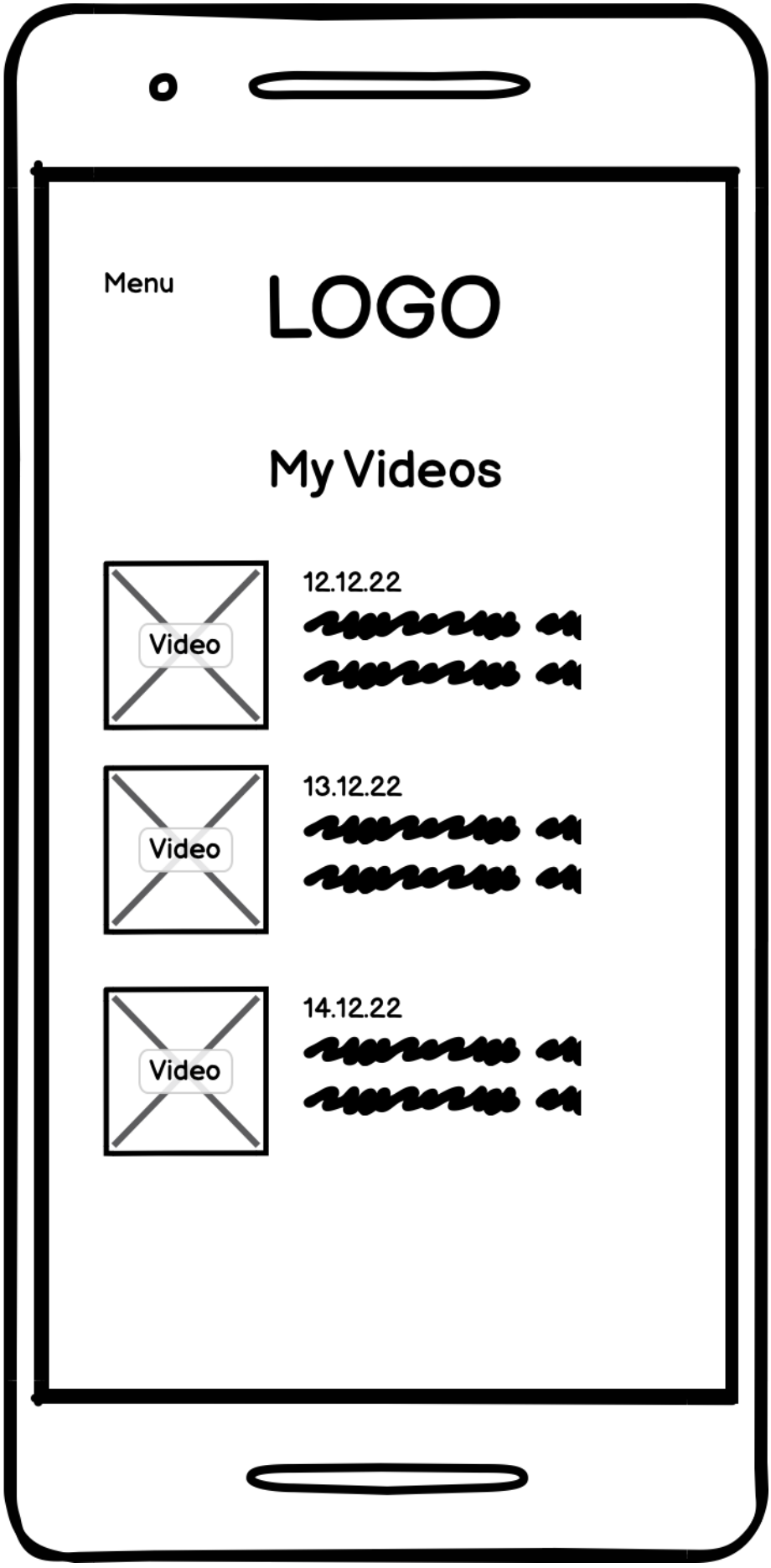
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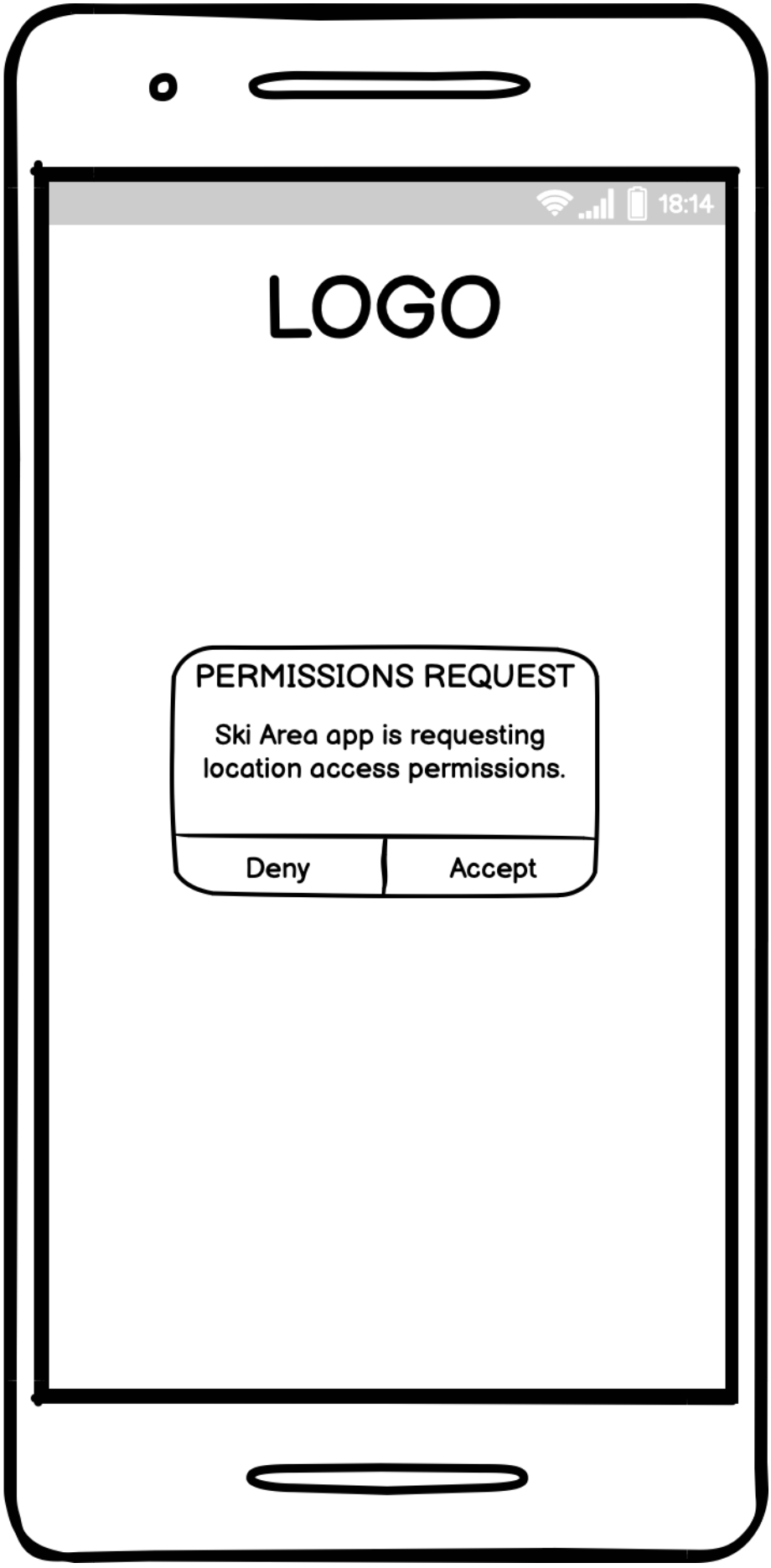
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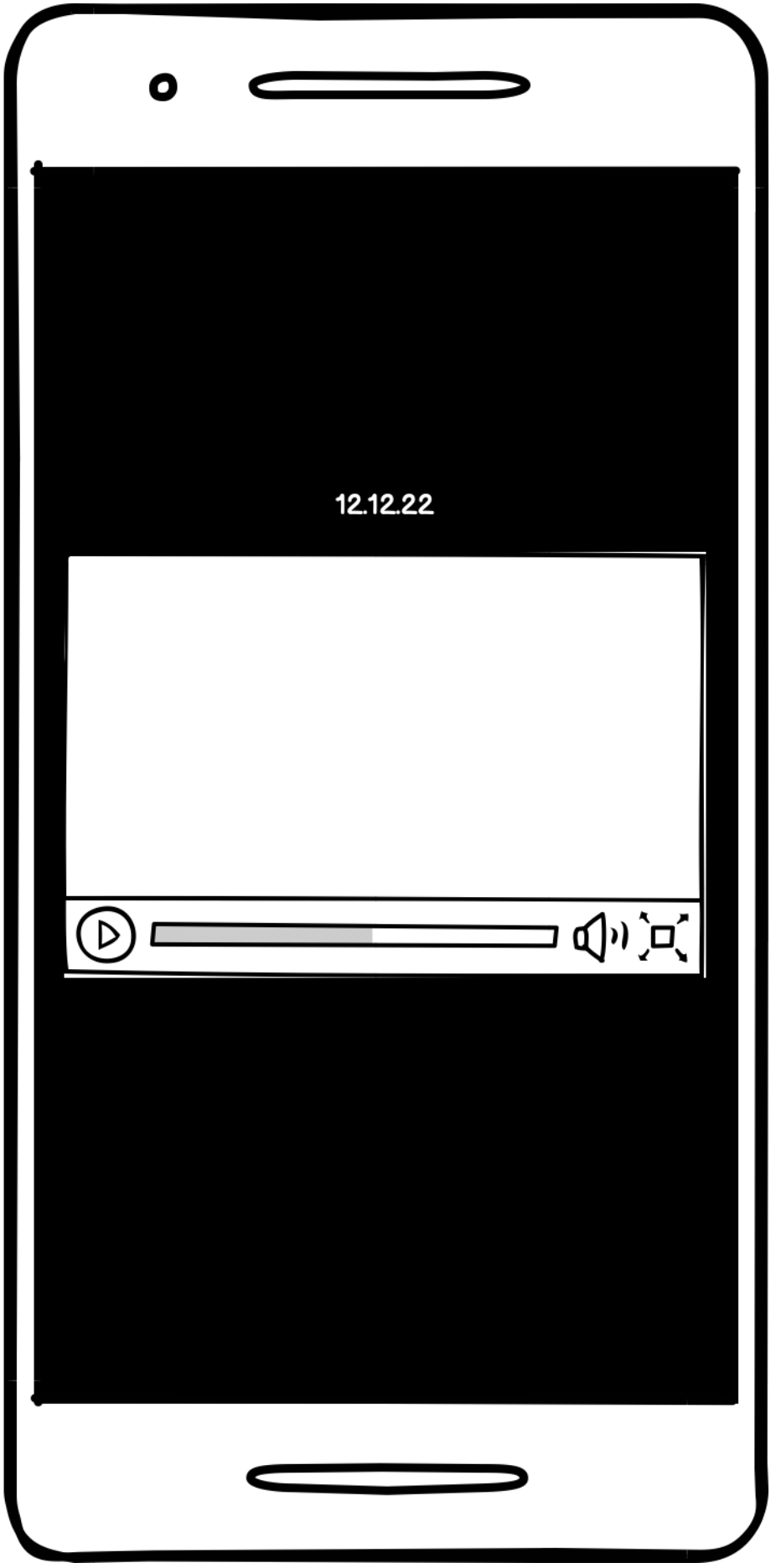
Accept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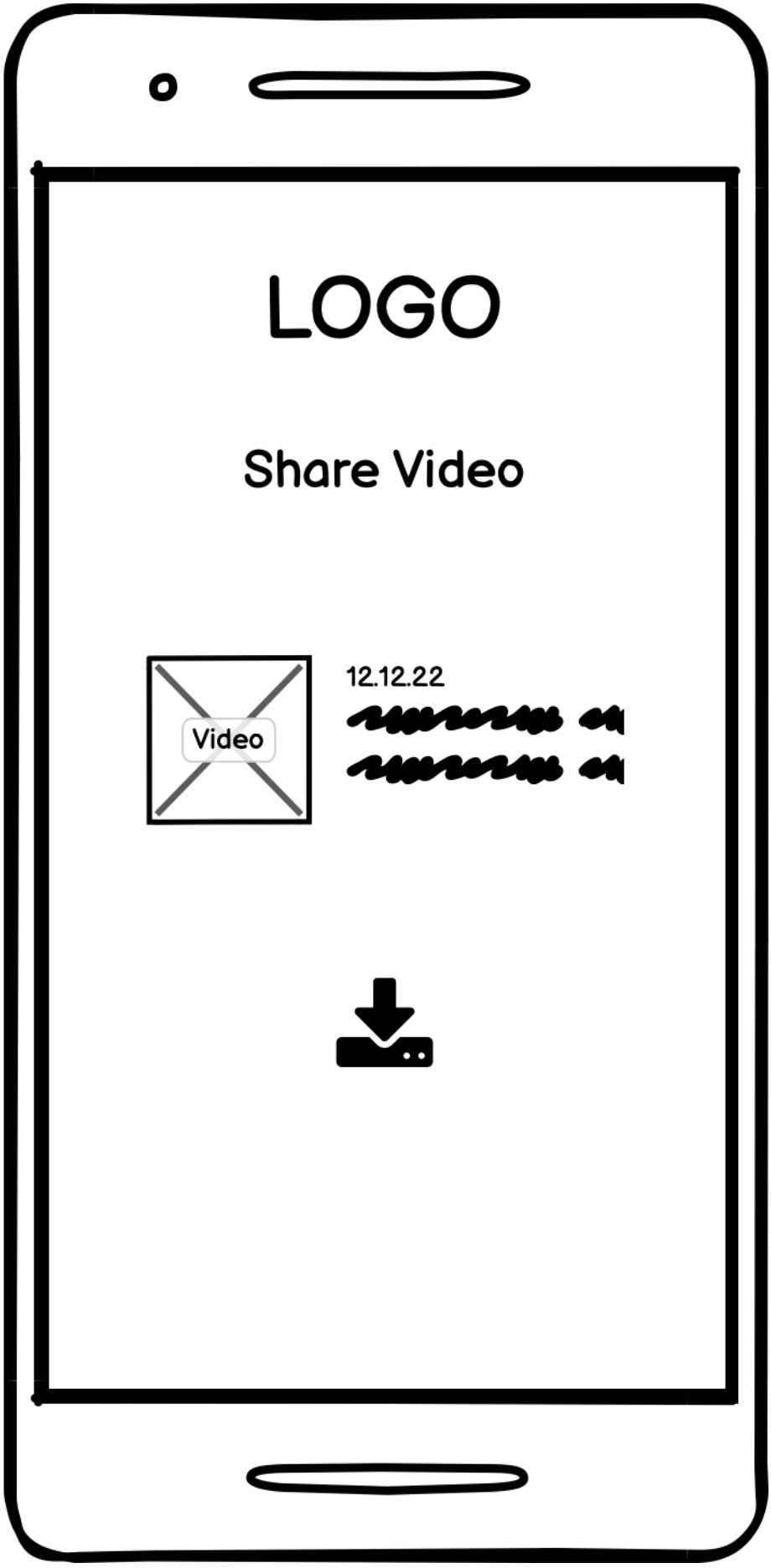
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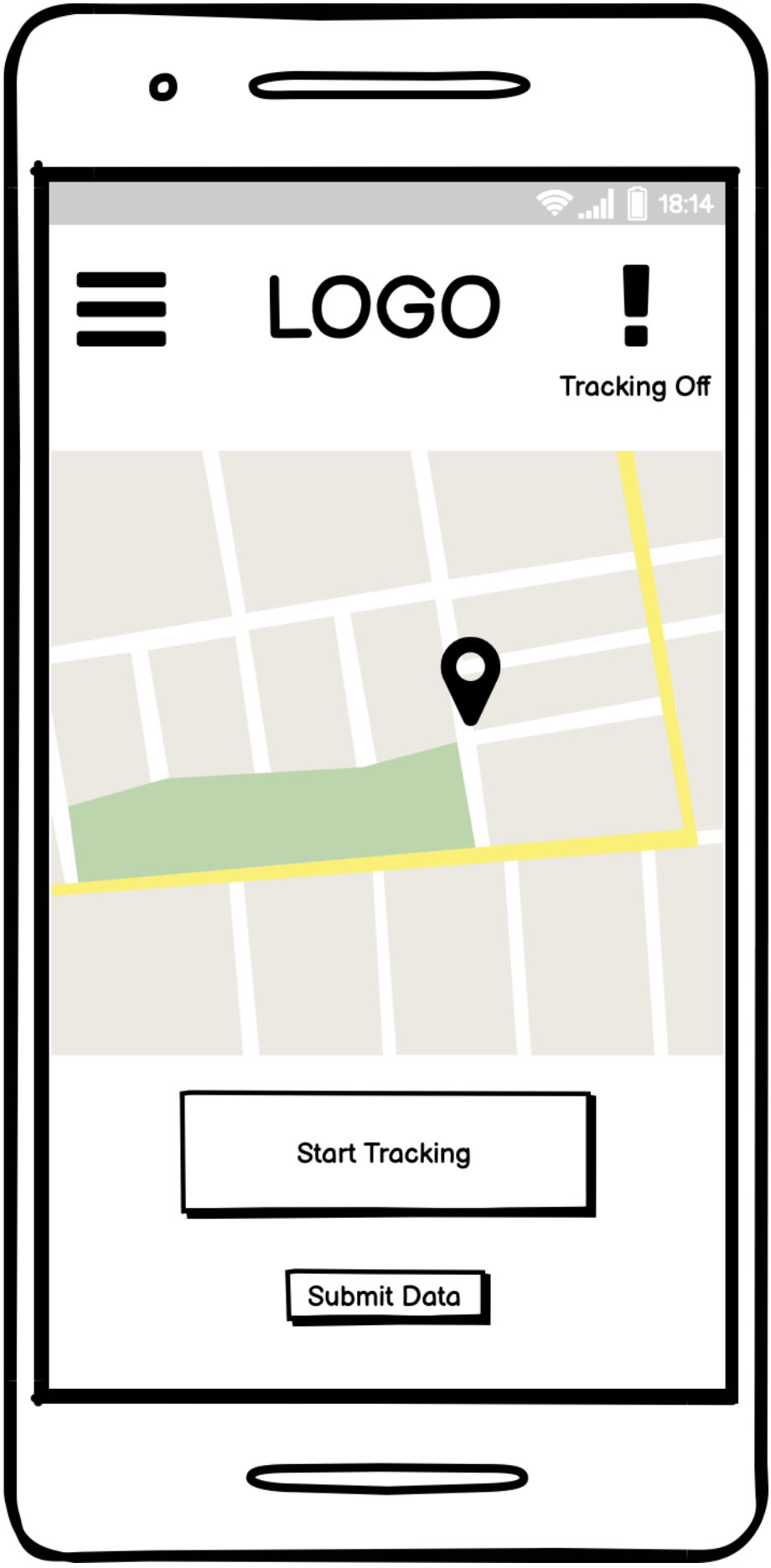
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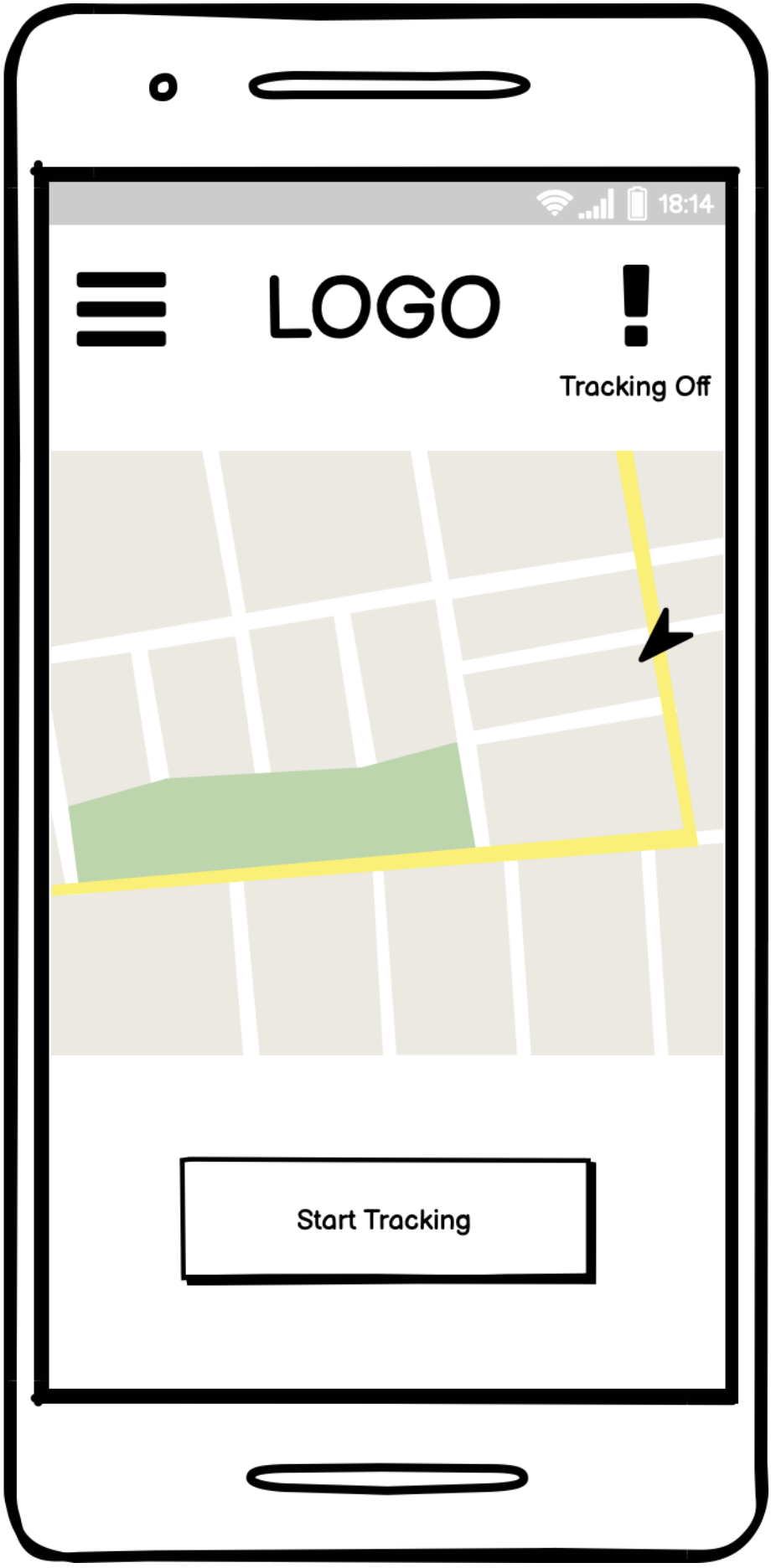
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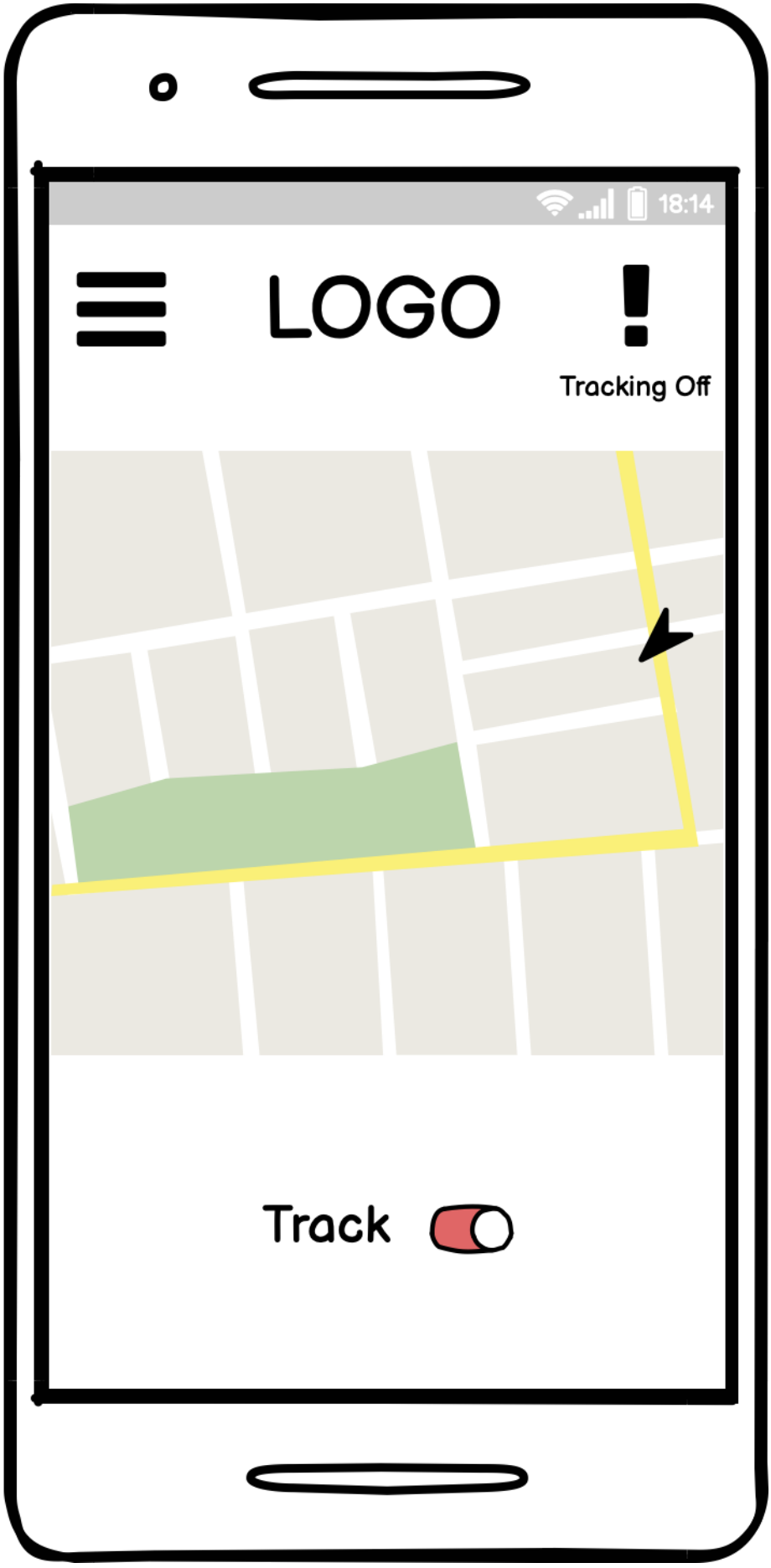
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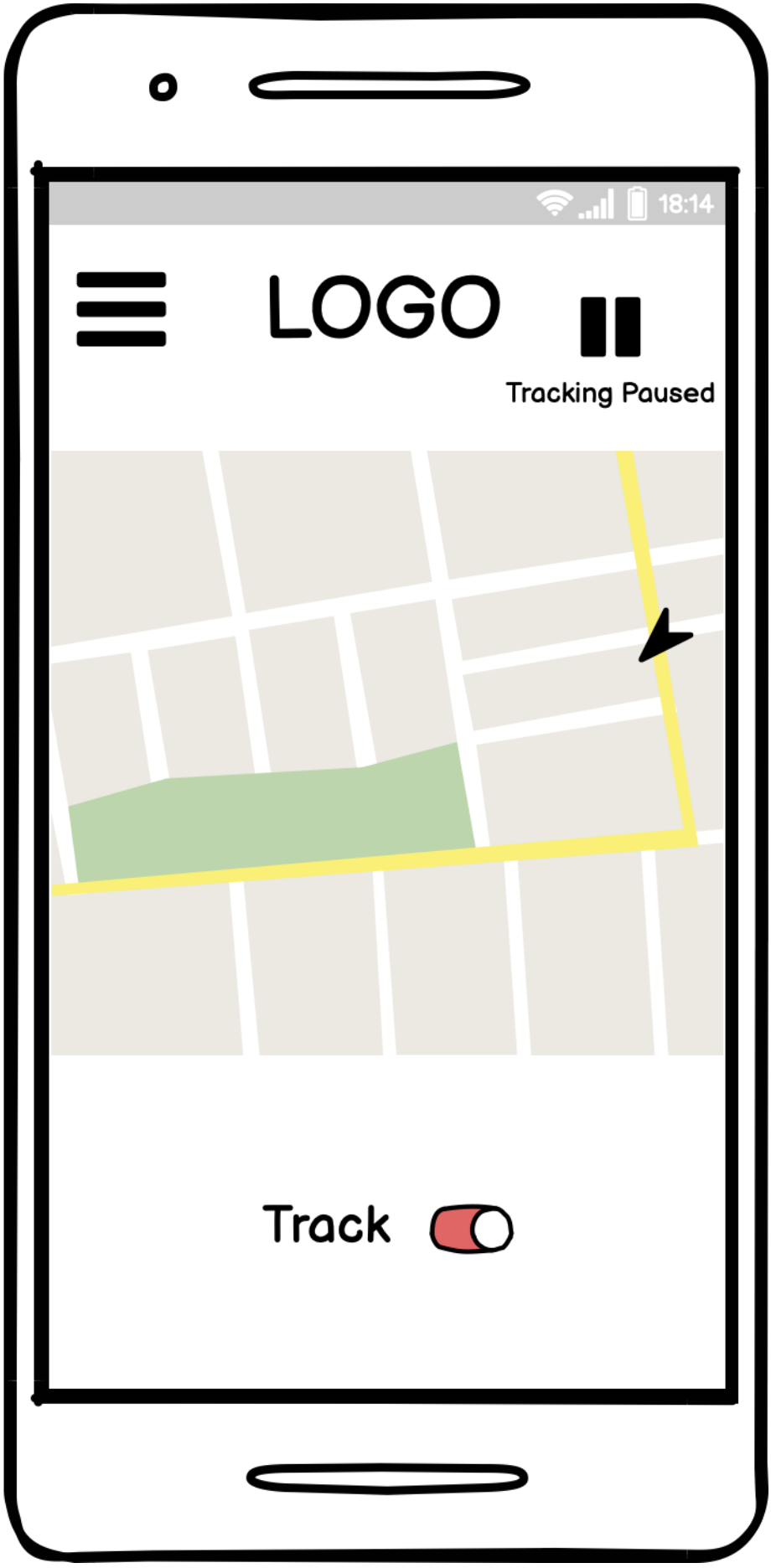
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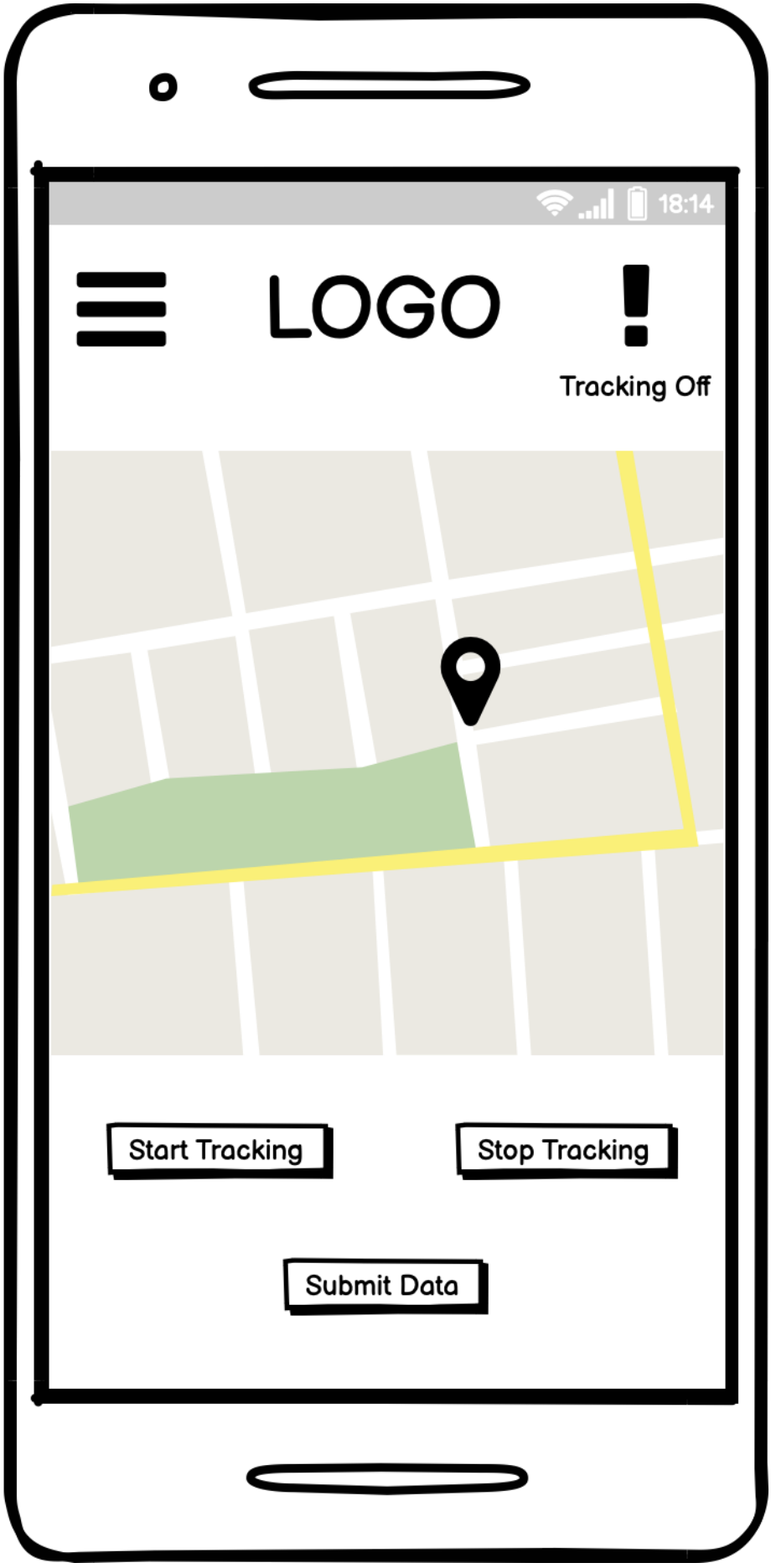
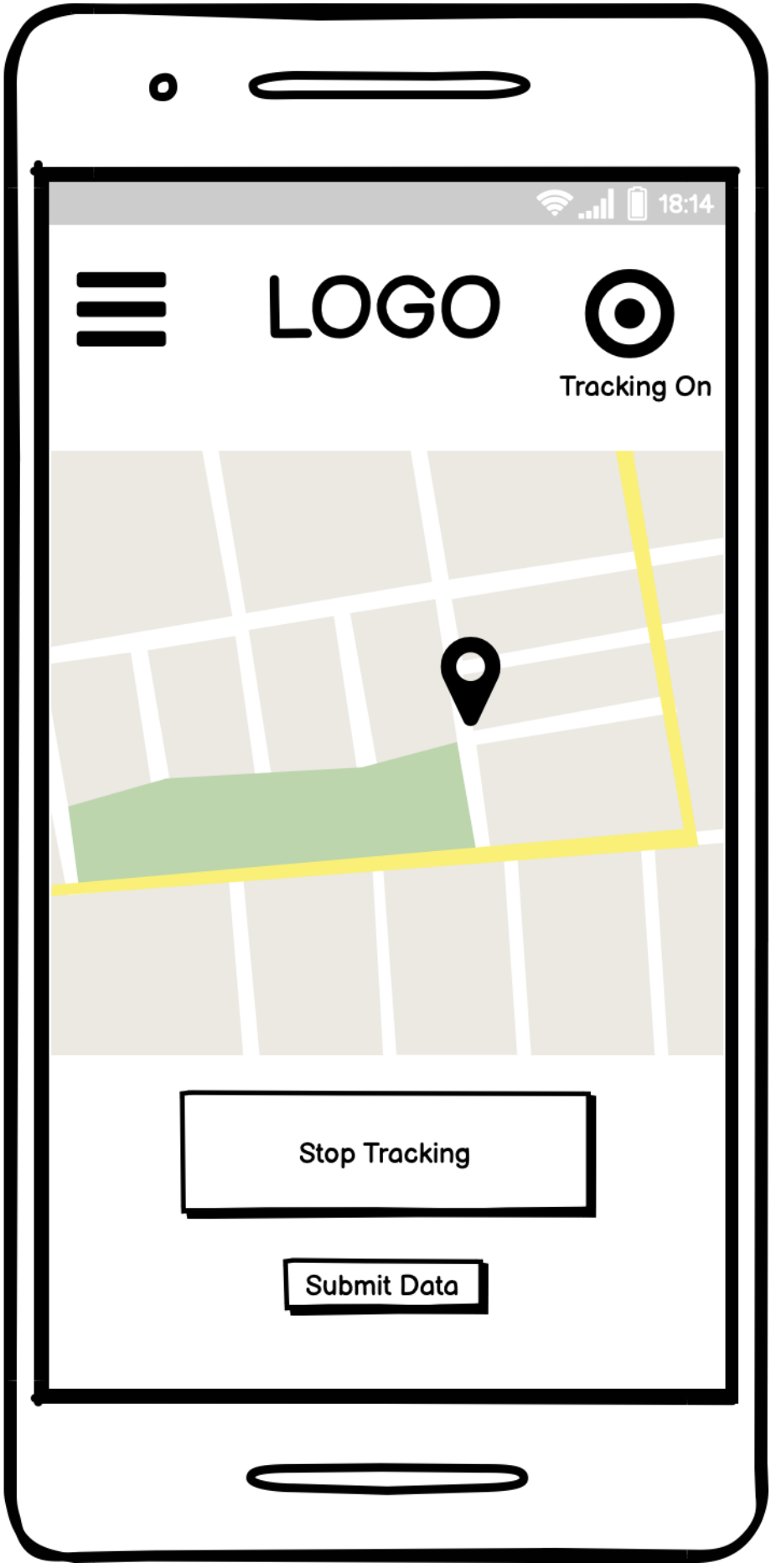
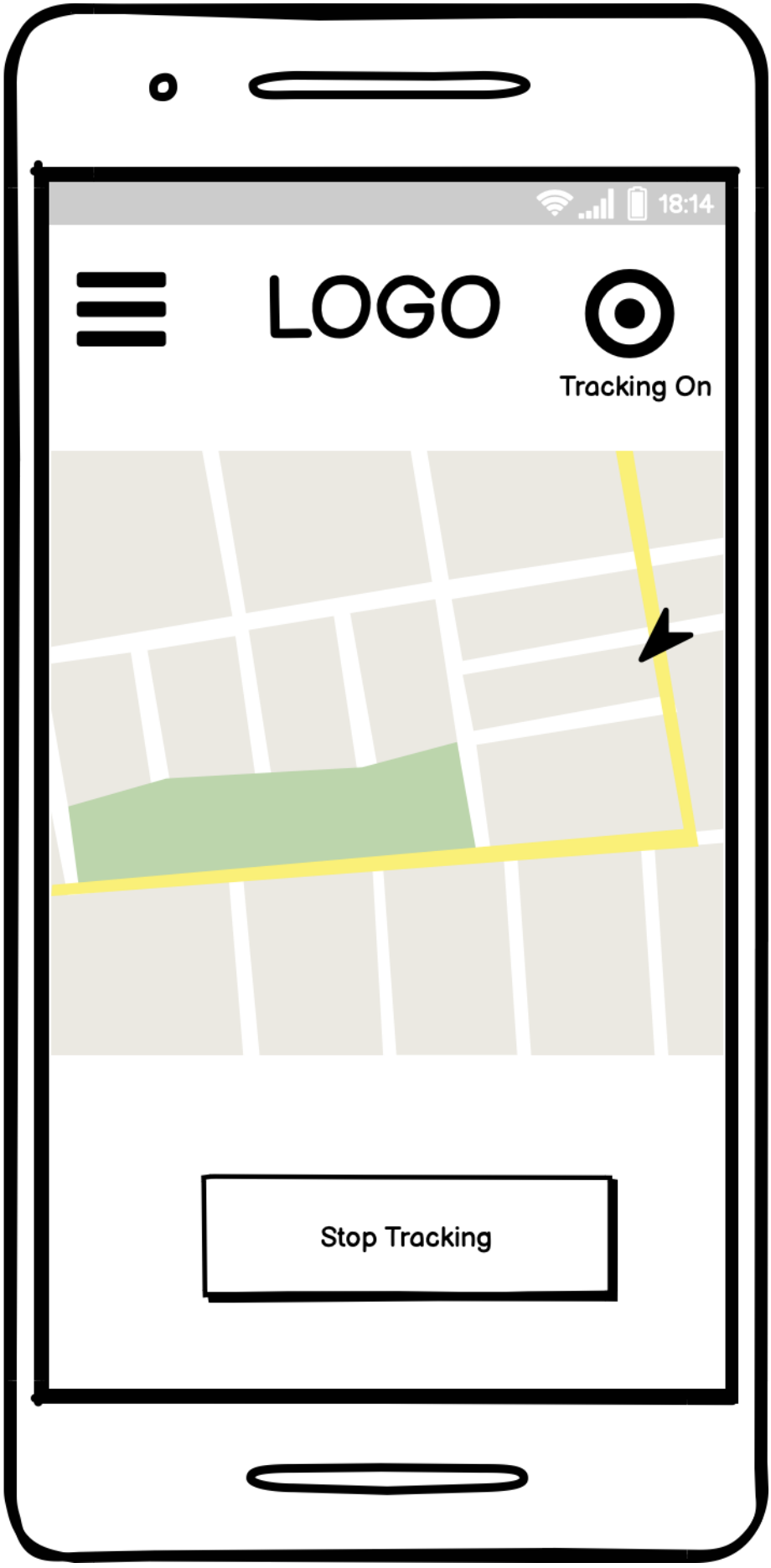
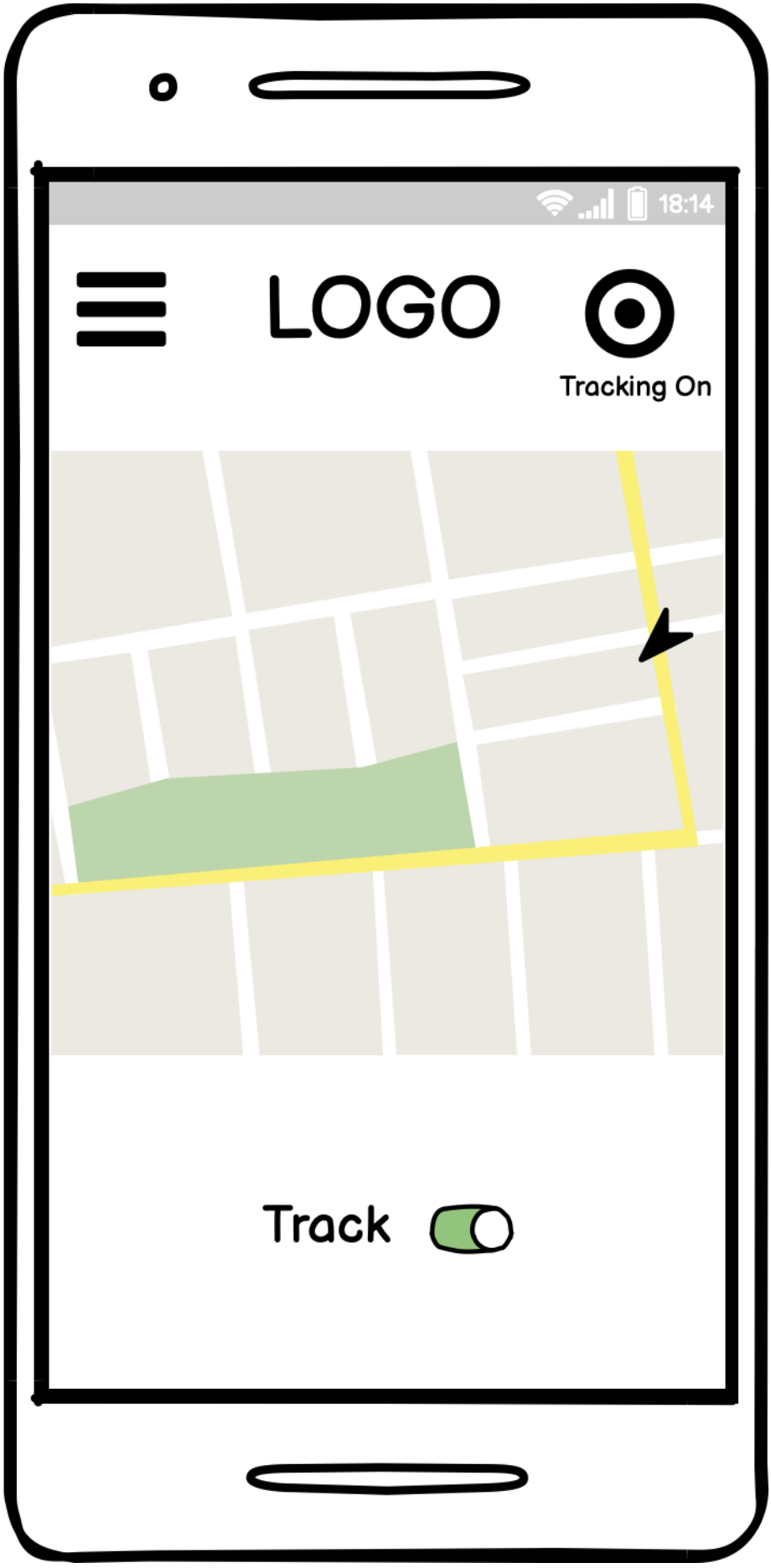
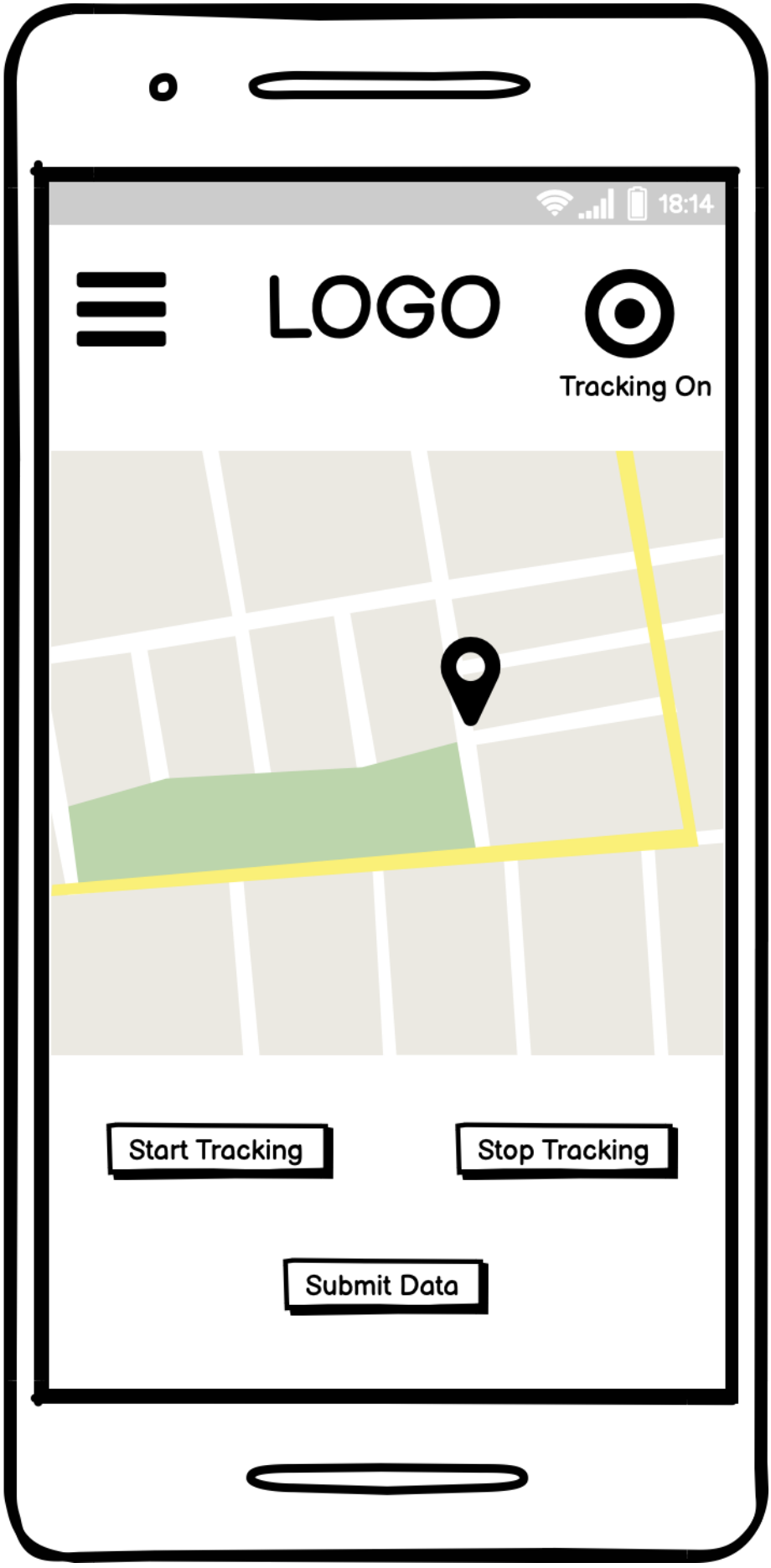
LOGO
Tracking Paused
Track


18:14
LOGO
Tracking Off
Start Tracking
Stop Tracking
Submit Data


18:14
LOGO
Tracking On
Stop Tracking
Submit Data

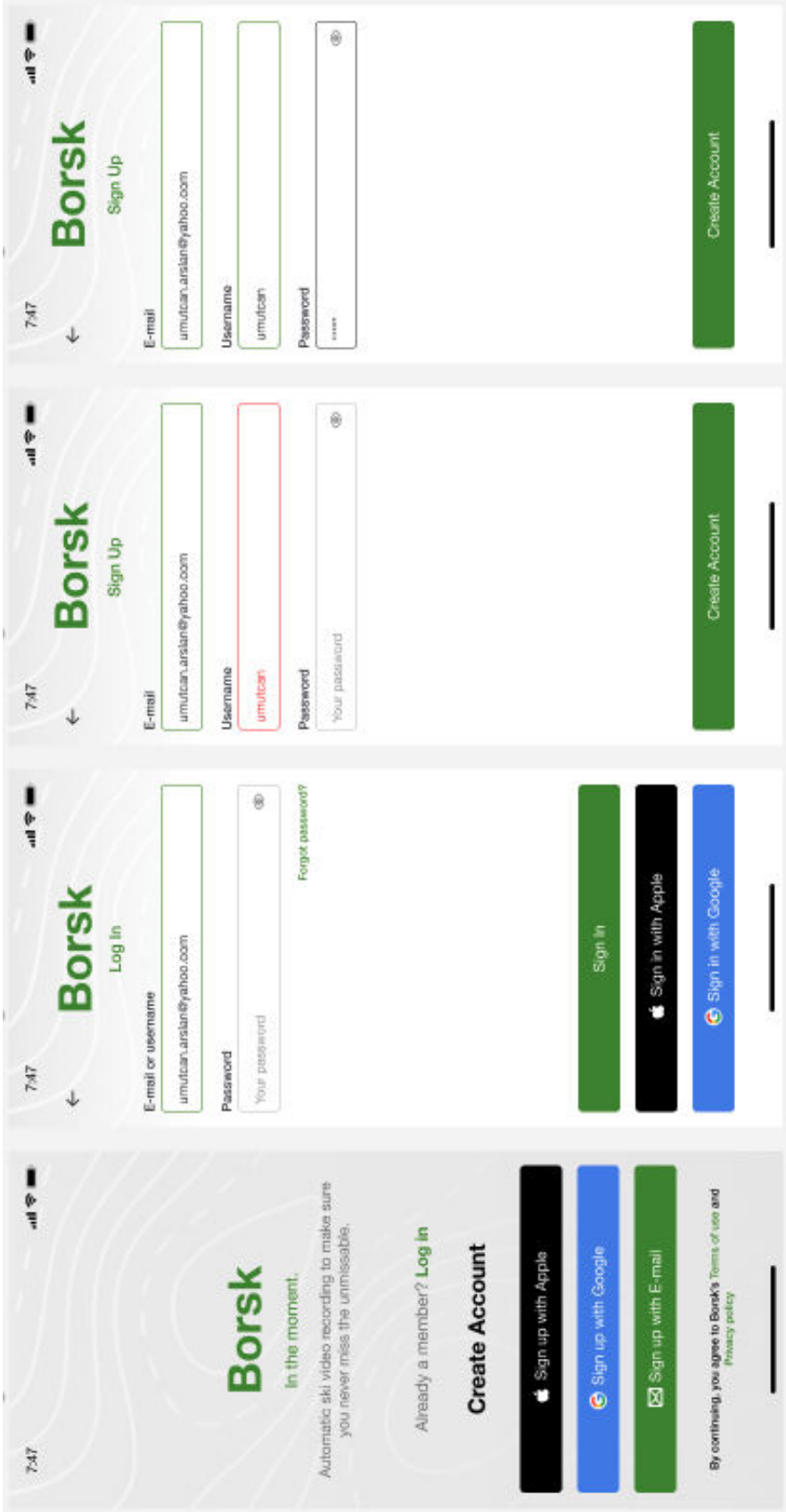

18:14
LOGO
Tracking On
Stop Tracking


18:14
LOGO
Tracking On
Track

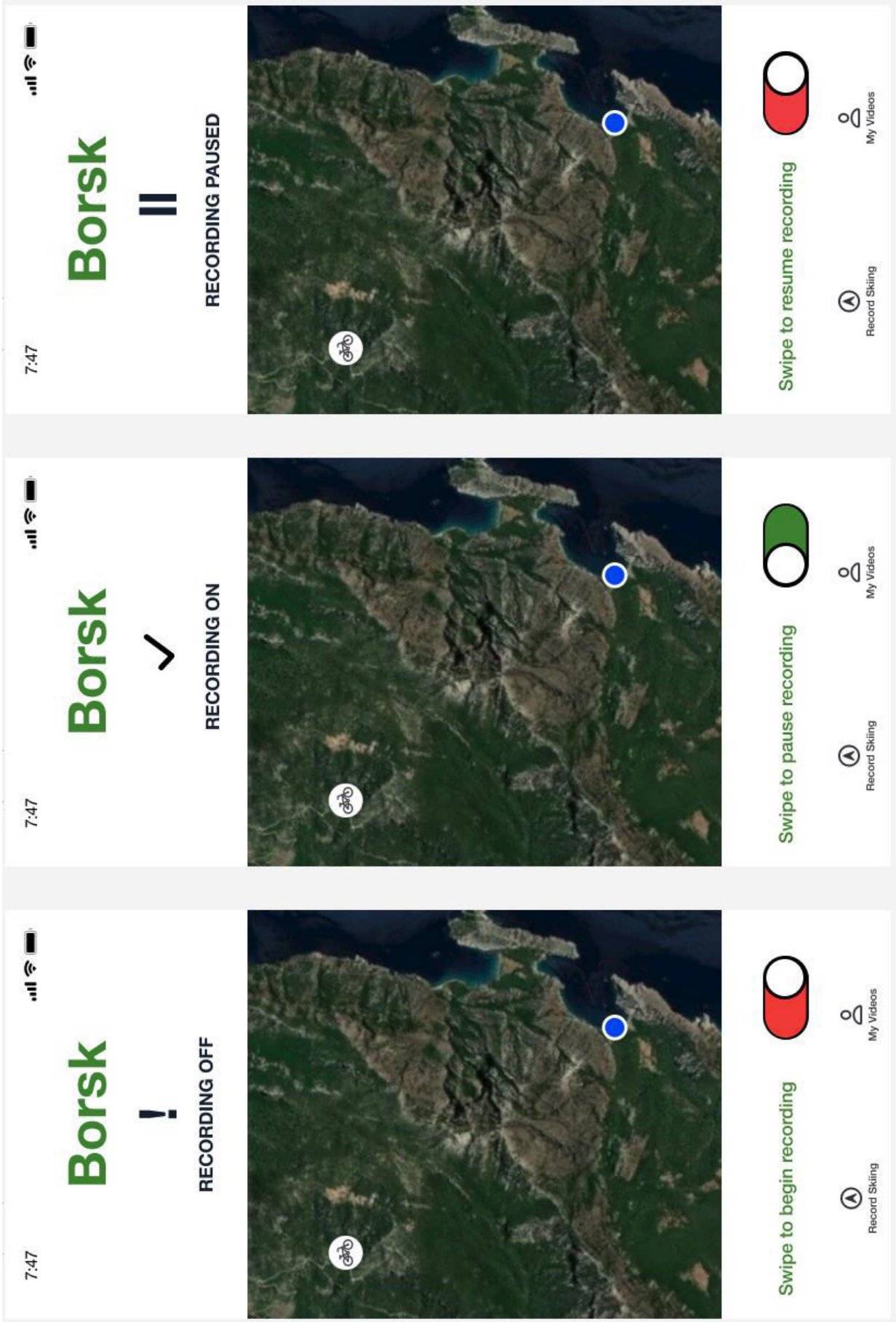

18:14
LOGO
Tracking On
Start Tracking
Stop Tracking
Submit Data

x. Figma Designs

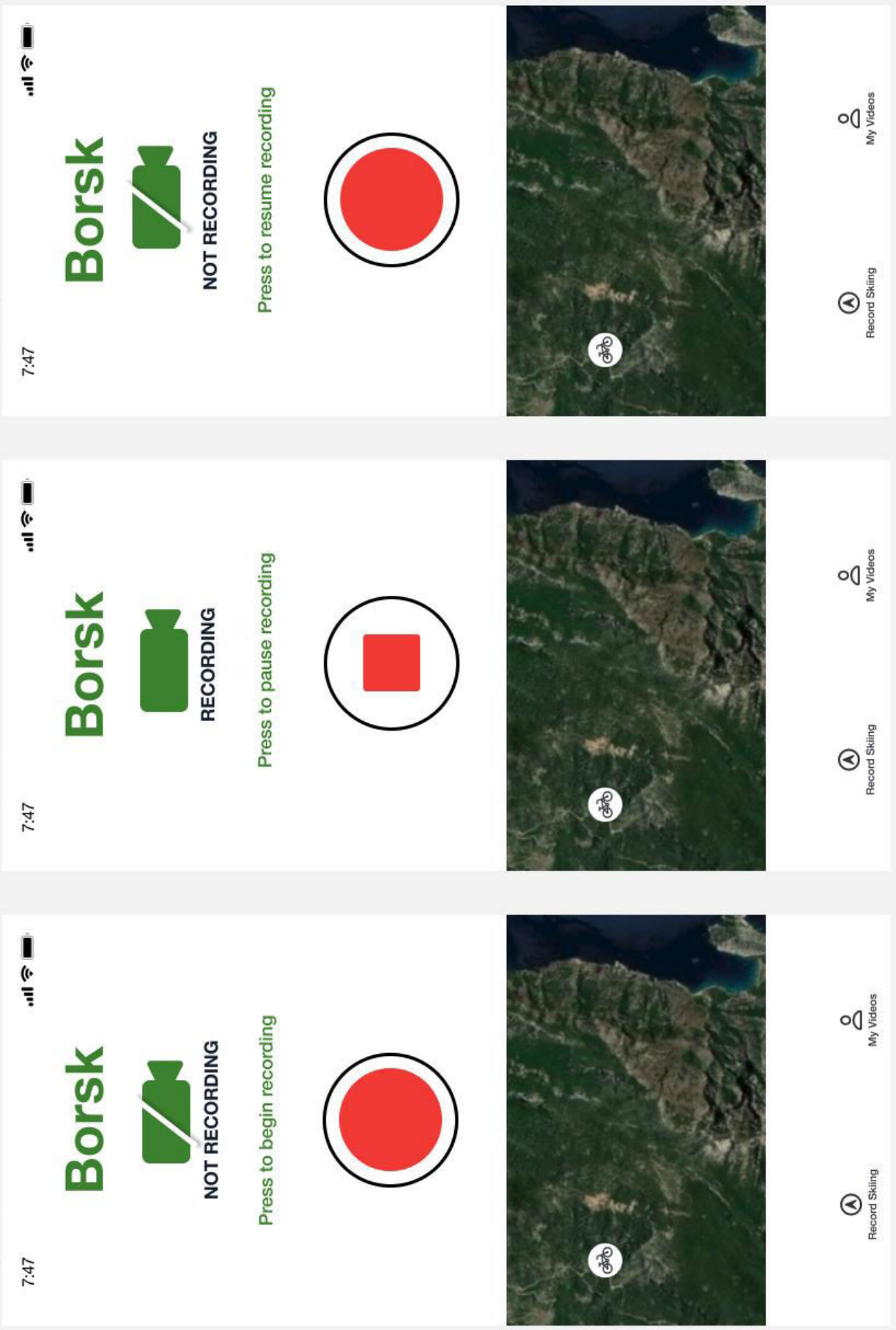
Home Screens



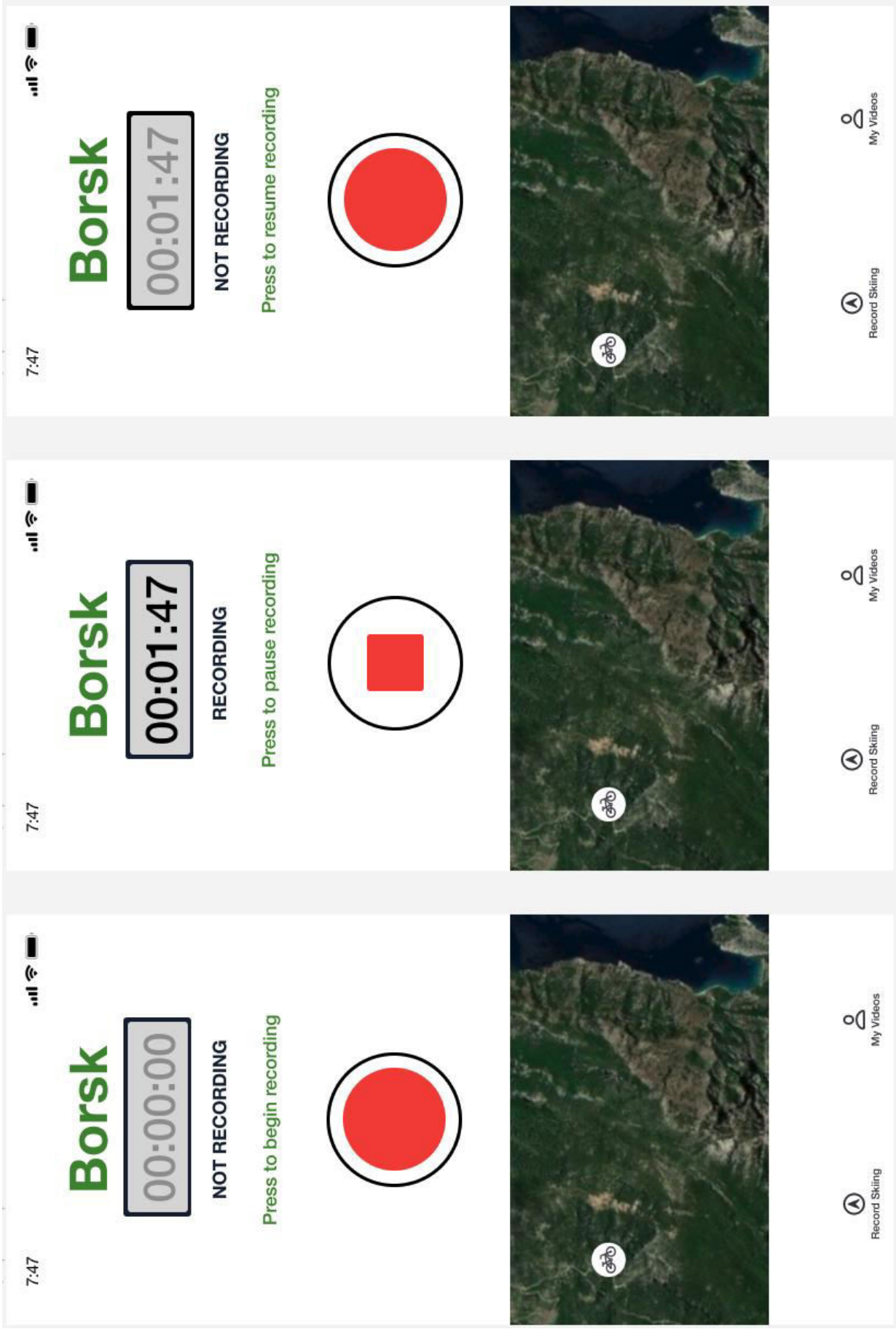
Operating Screens v1



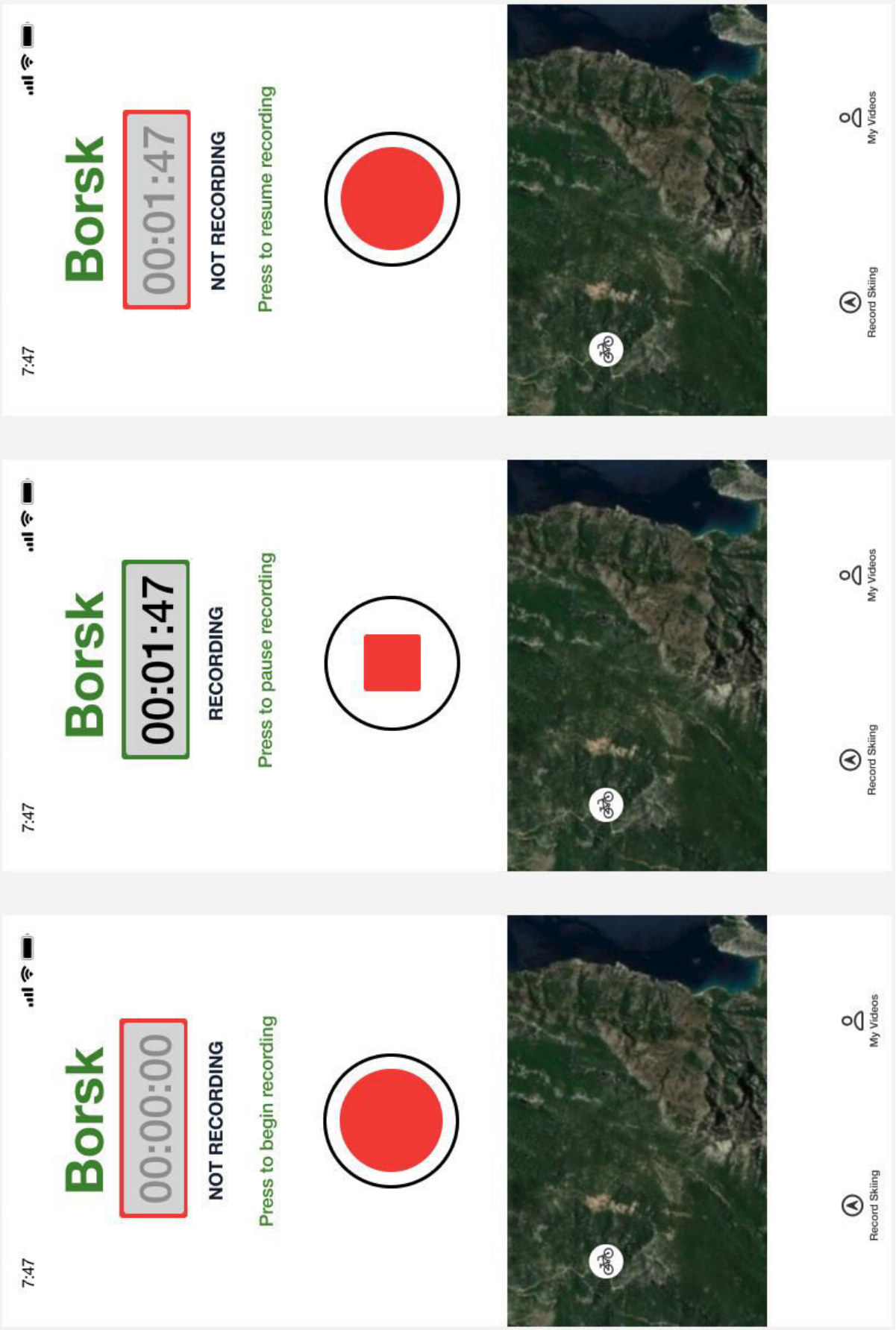
Operating Screens v2



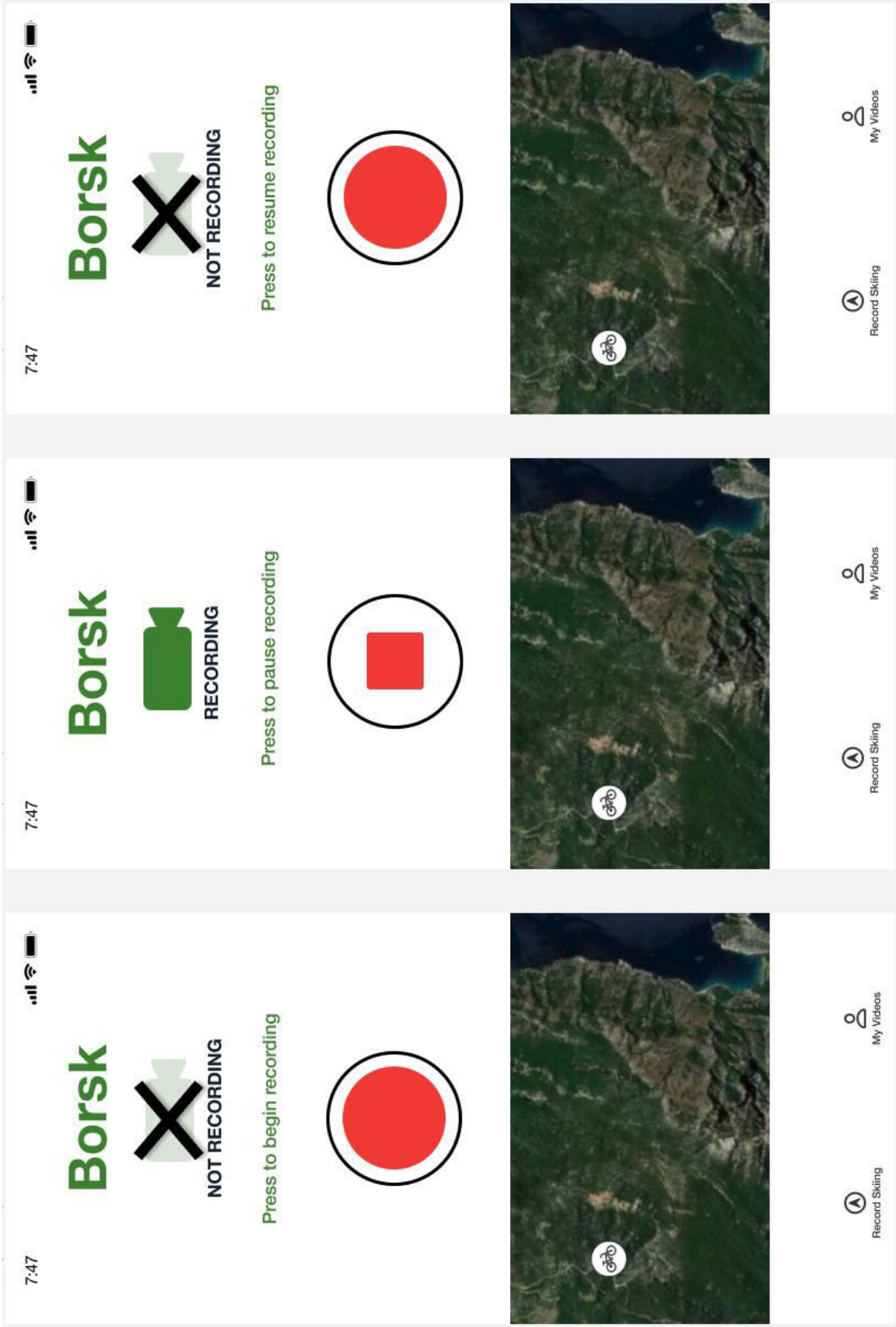
Operating Screens v3



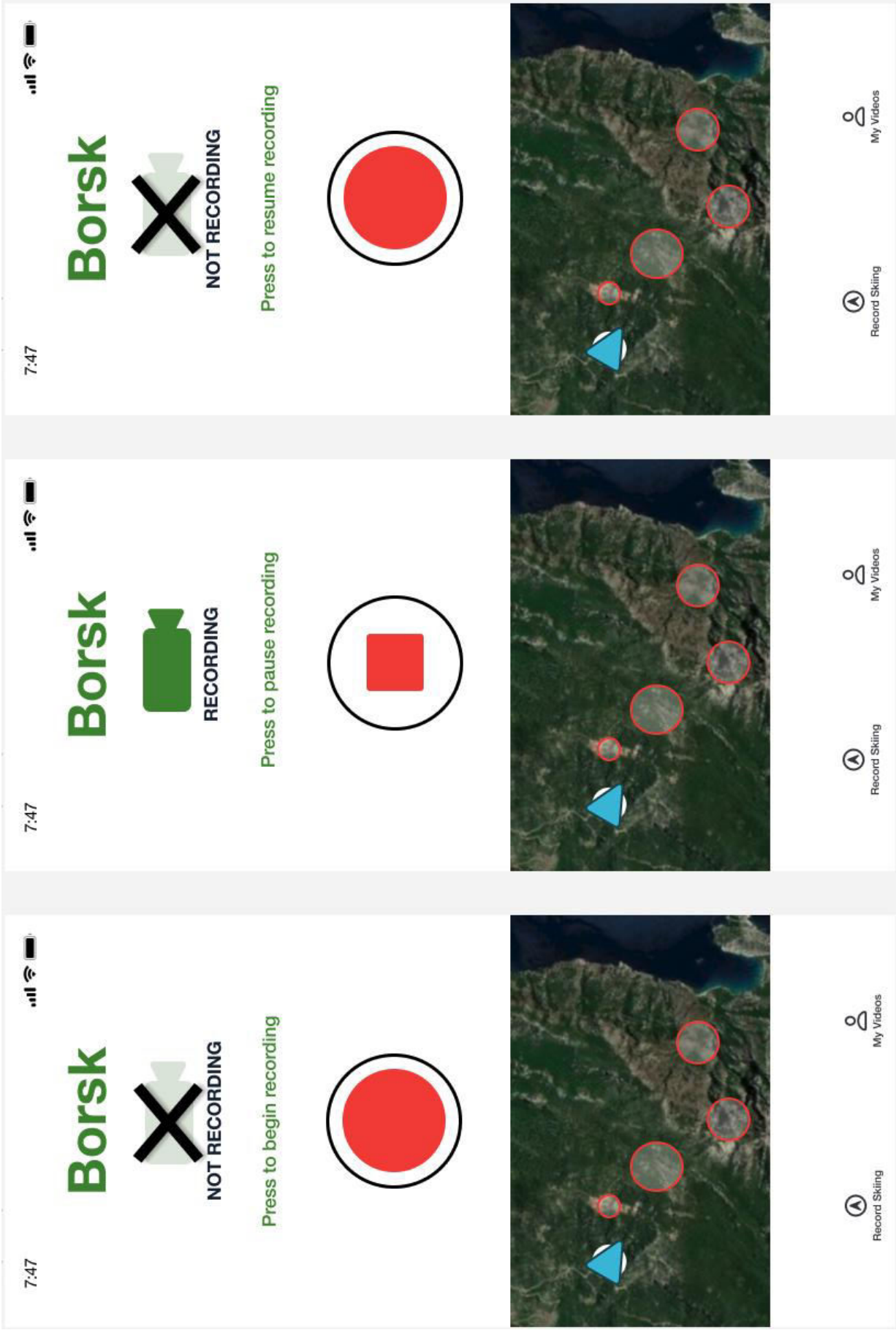
Operating Screens v4



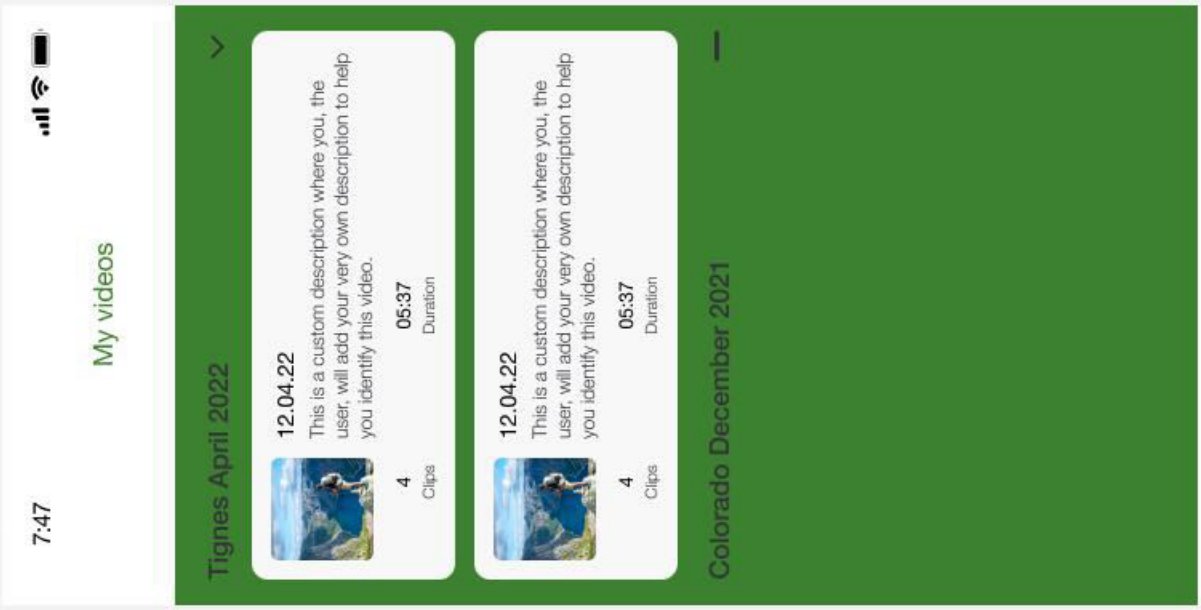
Operating Screens v5



Operating Screens v6

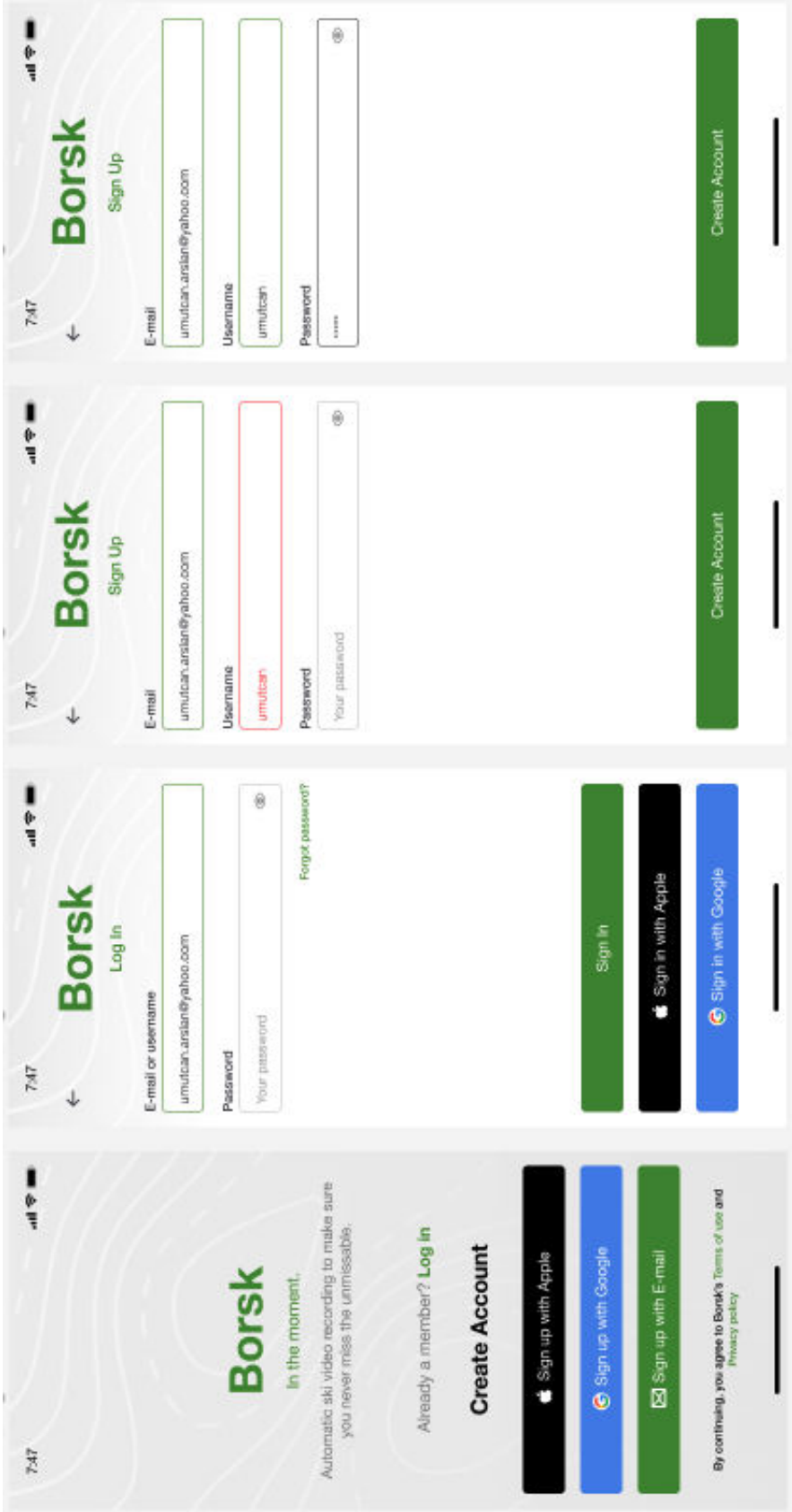


Review Screens

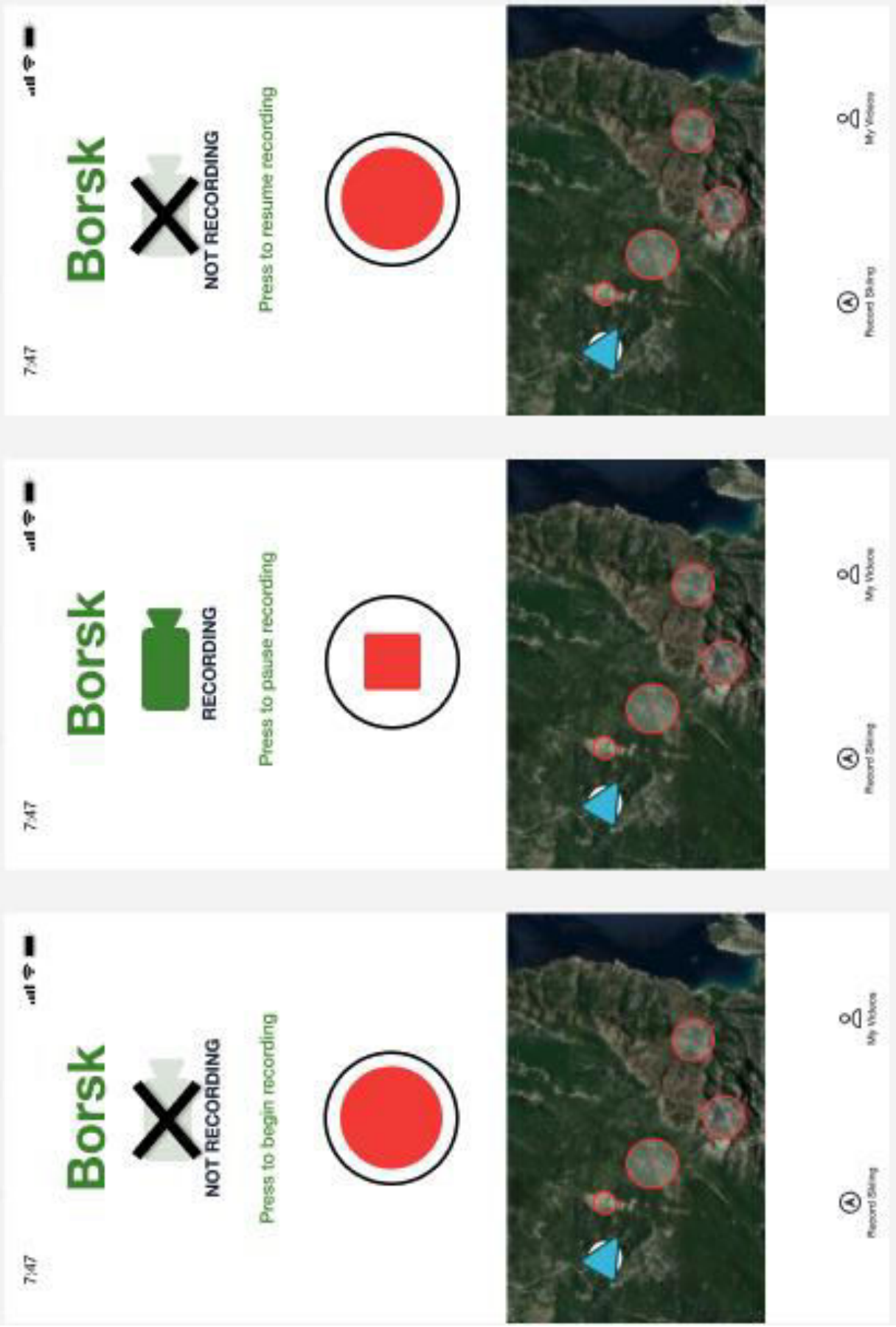


E. Appendix E – Final Design

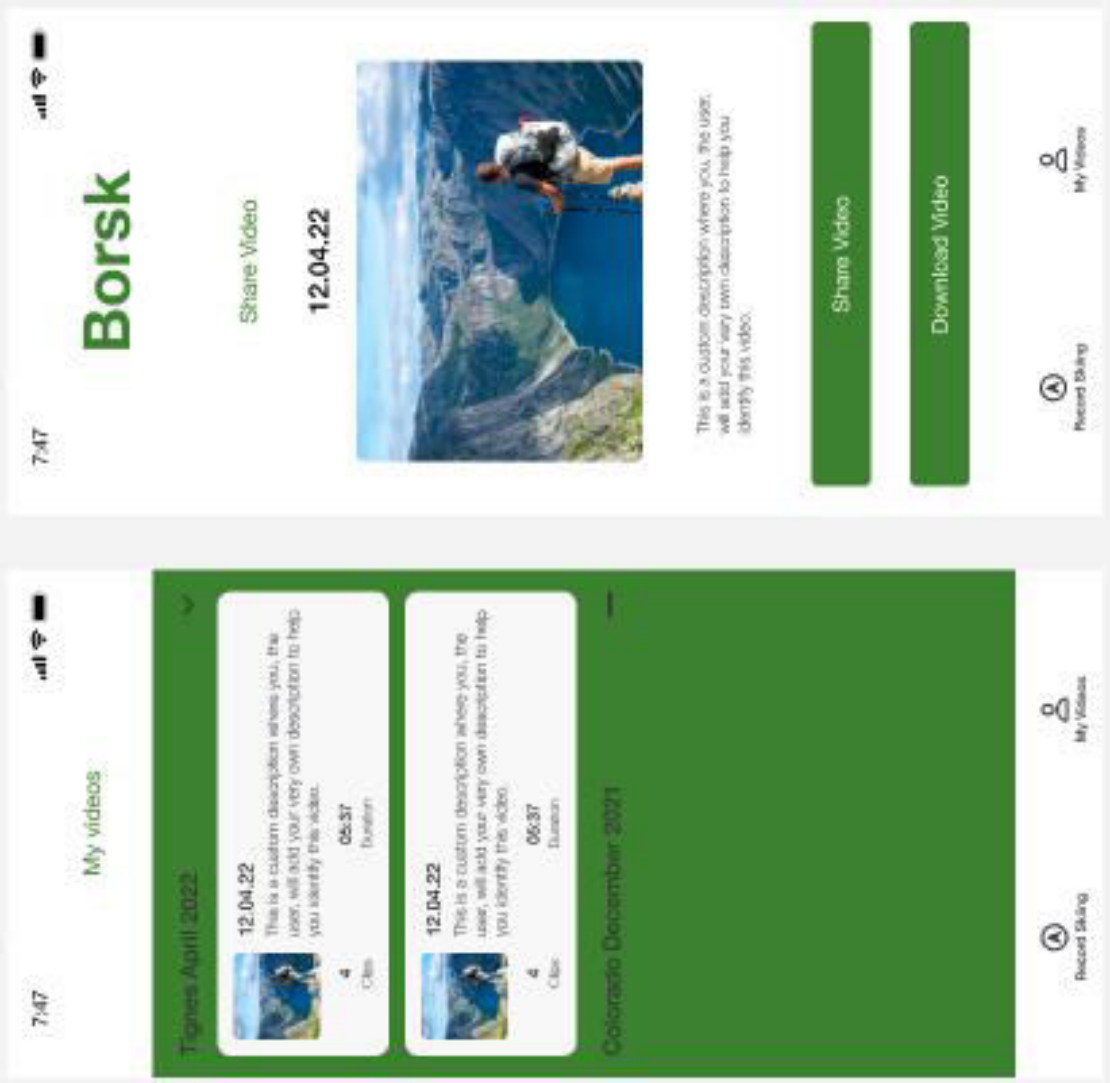
Final Home Screens



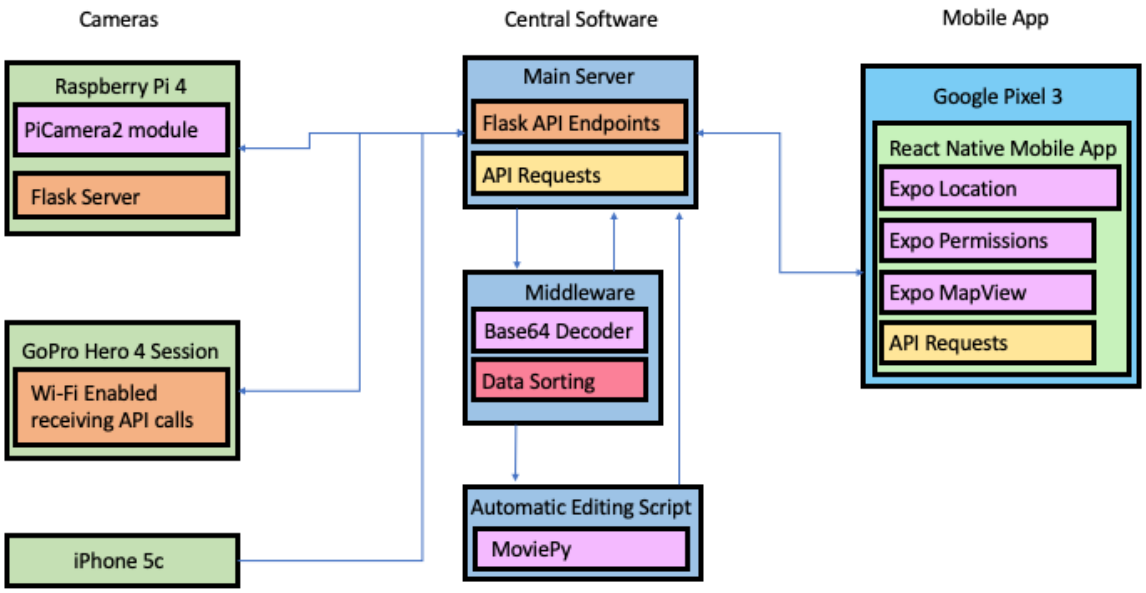
Final Operating Screens



Final Review Screens



F. Appendix F – Prototype Build Instructions



Overview

An entire system overview can be found above. It describes the three main sections of the prototype, the mobile app which collects location data and provides an interface which users interact with, the central software which controls camera recording, data sorting, retrieval of footage, decoding of footage, and automatic editing, and finally the cameras, two of which are remotely triggered to begin recording and return the footage.

This appendix will provide build instructions and code snippets for each section of the system, to the level of detail that an intermediate programmer could recreate the system.

Mobile App Build Instructions

The mobile app uses the Expo environment and libraries in a React Native JS file. The essential libraries used are Expo MapView and Expo Location.

```
React.useEffect(() => {
  (async () => {
    let { status } = await Location.requestForegroundPermissionsAsync() &&
    await Location.requestBackgroundPermissionsAsync();
    if (status !== 'granted') {
      console.log('Permission to access location was denied');
      return;
    }
```

Firstly permission must be obtained to allow the app to track location.

```
//Regions that the scopes of the cameras cover
const regions= [
  {
    id:"cam_A",
    inside: false,
    cen: {
      lat: 52.5250581,
      lon: -1.460638
    },
    radius: 0.005, //km,
    start: 0,
    end: 0
  },
```

The app must create regions for each camera. A region represents the scope of view of each camera. The region object has coordinates, an ID, and radius. It also contains start and end attributes which will hold the timestamps that the user enters and exits this region.

```
//Method to change recording status
function changeRecordingStatus() {
  if (recordingStatus == false) {
    recordingStatus = true
    console.log("CHANGED RECORDING STATUS TO TRUE")
    buttonText = "Stop Recording"
    instructionalText = "Press to pause recording"
    visibleStatus = "RECORDING"
    cameraImage =  cameraImg
    buttonImg = stopRecordImg;
  } else if (recordingStatus == true) {
    recordingStatus = false
    console.log("CHANGED RECORDING STATUS TO FALSE")
    buttonText = "Start Recording"
    instructionalText = "Press to resume recording"
    visibleStatus = "NOT RECORDING"
    cameraImage =  slashCameraImg
    buttonImg = startRecordImg;
  }
}
```

When the user presses a button to start recording, the interactive app calls the changeRecordingStatus() function which changes both viewer visibility to allow and stop recording but also system functionality which starts and stops recording.

```
  <MapView
        style={styles.map}
        initialRegion={{
          latitude: 52.525019,
          longitude: -1.460665,
```

```
          latitudeDelta: 0.0009,
          longitudeDelta: 0.0009,
      }}
      showsUserLocation={true}
      onUserLocationChange={(e) => {
        if (recordingStatus == true) {
          console.log("onUserLocationChange", e.nativeEvent);
        console.log("HERE");
        checkCoords(
          e.nativeEvent.coordinate.latitude,
          e.nativeEvent.coordinate.longitude,
          e.nativeEvent.coordinate.timestamp
        )
        }
```

On every user location change, the MapView component calls a function called checkCoords.

```
function checkCoords(latIn, lonIn, timeIn) {
  console.log("CHECKING")
  for (let i in regions) {
    var oldInside = regions[i].inside;
    console.log("DISTANCE: " + calcCrow(regions[i].cen.lat, regions[i].cen.lon,
latIn, lonIn) + " RADIUS: " + regions[i].radius)
    if (calcCrow(regions[i].cen.lat, regions[i].cen.lon, latIn, lonIn) <
regions[i].radius) {
      regions[i].inside = true;
    } else {
      regions[i].inside = false;
    }
    if (oldInside == false && regions[i].inside == true) {
      console.log("Entered region: " + regions[i].id + " at " + timeIn);
      regions[i].start = timeIn;
    } else if (oldInside == true && regions[i].inside == false) {
      console.log("Exited region: " + regions[i].id + " at " + timeIn);
      regions[i].end = timeIn;
    }
    console.log("OLD INSIDE:  " + oldInside + " NEW INSIDE: " + regions[i].inside);
    console.log(JSON.stringify(regions[i]));
  }
}
```

The checkCoords function then compares the user current location to assess whether the user is inside or outside of any of the camera region. If it finds that a user has just entered a region or just exited a region, it will note these timestamps in that region object.

```
<Button
        title="Submit Data"
        color='#4c8c2c'
```

```
        onPress={() =>
        //submitData()
        //testSubmitData()
        testPostData()
        }
      />
```

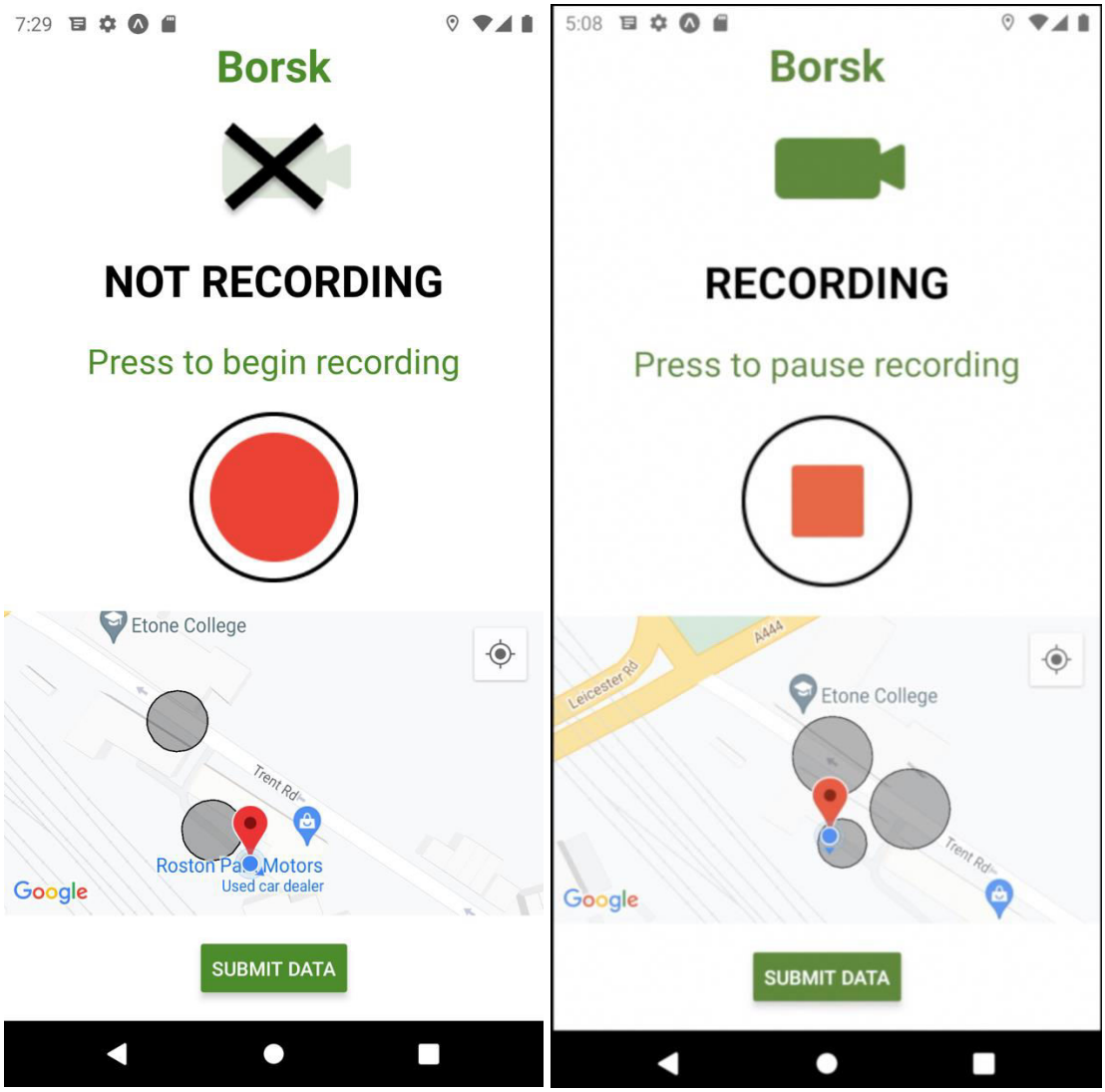
For the prototype system, a button was used to send an API Post containing the run data back to the main server. The above code snippet shows the frontend of this button.

```
const testPostData = async () => {

  const response = await fetch(`http://`+api+`/test/brandan`, {
        method: 'POST',
        headers: {
          Accept: 'application/json',
          'Content-Type': 'application/json',
          'Content-Length': 351
        },
        body:

          JSON.stringify({regions})


    })
    .then((response) => response.json())
    .then((json) => {
      console.log("RESPONSE: " + JSON.stringify(json))
      return json;
    })
  .catch ((error) => {
    console.error(error);
  });
};
```

This button then makes an API call, sending the region data back to the main server.

Prototype Screens

The prototype app also has a functional frontend, shown in the below screen captures.



Central Software Build Instructions

The central software is made up of a main server which runs via Flask and sorts incoming data. It also comprises of an automatic video editor using the MoviePy library.

```
def gpStartRecording():
    go_pro.video_settings(res="4k", fps="60")
    go_pro.shoot_video(duration=60)
    gpRecStartTime = time.time()*1000
    with open('gpRecStartTime.txt', 'w') as f:
        f.write(str(gpRecStartTime))
    return "GoPro recording started at: " + str(gpRecStartTime)
```

The GoPro recording is started remotely by calling the gpStartRecording function whilst on the machine (i.e. not through an endpoint).

```
@app.route("/startCams")
def startAll():
```

```
    #request pi to start recording
    requests.get(piUrl + '/start')
```

The Pi camera recording can be started by using an endpoint as shown above.

```
@app.route("/submitData", methods=["POST"])
def submitData():
        content_type = request.headers.get('Content-Type')
        if (content_type == 'application/json'):

            #map out the json data to new region
            json = request.json
            for region in json:
                id = region["id"]
                start = region["start"]
                end = region["end"]
                region = Region(id, start, end)
                RegionArray.append(region)
                print("CAM ID " + region.camId)
                print("TIME ENTERED " + str(region.timeEntered))
                print("TIME EXITED " + str(region.timeExited))

            return "Got the regions!"

        else:
            return 'Content-Type not supported!'
```

The /submitData is the route which the app makes the POST request to. It accesses the sent JSON object, storing the attributes locally.

```
def getPiClipv2():
    #get the pi clip from PiServer
    response = requests.get(piUrl+'/get')

    with open("piClip.txt", "wb") as fd:
        for chunk in response.iter_content(100):
            fd.write(chunk)

    #base64 decode the clip
    with open("rawPiFootage.mp4", "wb") as videoFile:
        with open("piClip.txt", "rb") as file:
            text = file.read()
            videoFile.write(base64.b64decode(text))

    #Edit the pi clip based on camA region data
    piClipStartTimestamp = 0
    piClipStartTimestamp = RegionArray[0].timeEntered
    print("gpClip will start at " + str(piClipStartTimestamp))
    piClipEndTimestamp = 0
    piClipEndTimestamp = RegionArray[1].timeExited
```

```
    print("gpClip will end at " + str(piClipEndTimestamp))

    #determine the seconds for beginning and ending the cut of the pi clip
    beginCutInMilli = piClipStartTimestamp - recStartTimeStamp
    beginCutInSeconds = round(beginCutInMilli/1000, 2)
    endCutInMilli = piClipEndTimestamp - recStartTimeStamp
    endCutInSeconds = round(endCutInMilli/1000, 2)
    print("WILL BEGIN PI CUT AT: ", beginCutInSeconds, " WILL END PI CUT AT: ",
endCutInSeconds)

    #cut the clip
    print("Cutting the pi footage")
    loadtitle = "rawPiFootage.mp4"
    savetitle = "piClip.mp4"
    video = mpy.VideoFileClip(loadtitle)
    clip = video.subclip(beginCutInSeconds, endCutInSeconds)
    # save file
    clip.write_videofile(savetitle, threads=4, fps=24,
    codec=vcodec,
    preset=compression,
    ffmpeg_params=["-crf",videoquality])
    video.close()

    return "Pi Clip Edited and Ready"
```

The central software can get the footage from the Pi through a GET request. It must then decode the clip which is sent as Base64 encoded. Once decoded, the clip is edited to the timestamps which the user's region object contained.

```
#get the raw footage
def gpGetFootage():
    if go_pro.IsRecording == 1:
        return "go pro still recording"
    else:
        go_pro.downloadLastMedia(custom_filename="rawGPFootage.mp4")
        return "got last media"
```

GoPro footage can be retrieved using this function, which makes use of the unofficial [GoPro API for Python](#).

```
def editGPClip():
    #read txt file to find gp rec start time
    with open('gpRecStartTime.txt') as f:
        lines = f.read()
        gpRecStartTime = int(float(lines))
        print("gp Rec Start Time " + str(gpRecStartTime))
        f.close()

    #Edit the goPro clip based on camB region data
    gpClipStartTimestamp = 0
    gpClipStartTimestamp = RegionArray[1].timeEntered
```

```
    print("gpClip will start at " + str(gpClipStartTimestamp))
    gpClipEndTimestamp = 0
    gpClipEndTimestamp = RegionArray[1].timeExited
    print("gpClip will end at " + str(gpClipEndTimestamp))

    #determine the seconds for beginning and ending the cut of the gopro clip
    beginCutInMilli = gpClipStartTimestamp - gpRecStartTime
    beginCutInSeconds = round(beginCutInMilli/1000, 2)
    endCutInMilli = gpClipEndTimestamp - gpRecStartTime
    endCutInSeconds = round(endCutInMilli/1000, 2)
    print("WILL BEGIN CUT AT: ", beginCutInSeconds, " WILL END CUT AT: ",
endCutInSeconds)

    #cut the clip
    print("Cutting the goPro footage")
    loadtitle = "rawGPFootage.mp4"
    savetitle = "gpClip.mp4"
    video = mpy.VideoFileClip(loadtitle)
    clip = video.subclip(beginCutInSeconds, endCutInSeconds)
    # save file
    clip.write_videofile(savetitle, threads=4, fps=24,
    codec=vcodec,
    preset=compression,
    ffmpeg_params=["-crf",videoquality])
    video.close()

    return "GP Clip Edited and Ready"
```

The GoPro clip can then be edited based on the timestamps from the regions object.

```
def stitchClipsTogether():
    #Stitch the two clips together
    print("Stitching the two clips")
    piClip = mpy.VideoFileClip("piClip.mp4")
    gpClip = mpy.VideoFileClip("gpClip.mp4")
    final = mpy.concatenate_videoclips([piClip, gpClip])
    final.resize(width=480).write_videofile("result.mp4", threads=4, fps=24,
    codec=vcodec,
    preset=compression,
    ffmpeg_params=["-crf",videoquality])
    return "clips stitched together"
```

The clips can then be stitched together using this function which calls the MoviePy module.

```
@app.route("/downloadVideo")
def downloadVideo():
    return
send_from_directory(app.config['/Users/michaelclark/Library/CloudStorage/OneDrive-
UniversityofStAndrews/St Andrews - CS
MSc/Dissertation/Prototype/Main/src/result.mp4'], 'result.mp4', as_attachment=True)
```

The result can then be accessed via the above end point.

```
#python3 edit.py movie1.mov_00:00:02.000_00:00:04.000
movie2.mov_00:00:02.000_00:00:06.000
for arg in sys.argv:
    if arg == "edit.py": continue
    arr = arg.split("_")
    print(arr[0])
    print(arr[1])
    print(arr[2])
    video = mpy.VideoFileClip(arr[0])
    start = arr[1]
    end = arr[2]
    clip = video.subclip(start, end)
    clips.append(clip)

final_clip = mpy.concatenate_videoclips(clips)

# save file
final_clip.write_videofile(savetitle, threads=4, fps=24,
    codec=vcodec,
    preset=compression,
    ffmpeg_params=["-crf",videoquality])

video.close()
```

A dedicated script for editing multiple clips and stitching them together was also written and used for backup purposes. It uses the MoviePy library to take in the name and timestamps of editing multiple clips through a command line argument and edits and stitches those clips together, before saving them in an mp4 format.

Raspberry Pi Server Build Instructions

The Pi Server uses a Flask server to run as a server, uses the picamera2 library to control the attached camera module, and uses H264 encoder to send the footage to the main server.

```
@app.route('/start')
def start():
    global picam2
    picam2.start_recording(encoder, 'test0809.h264')
    return 'started recording'
```

The above start route begins the Pi camera recording.

```
@app.route('/stop')
def stop():
    global picam2
    picam2.stop_recording()
    command = shlex.split("MP4Box -add test0809.h264
0809.mp4".format(f='rawFootage.mp4'))
    output = subprocess.check_output(command, stderr=subprocess.STDOUT)
```

```
    return 'stopped recording'
```

The stop route stop the Pi camera recording and saves it.

```
@app.route('/get')
def getFullFootage():
    #base64 encode the clip
    with open("0809.mp4", "rb") as videoFile:
        text = base64.b64encode(videoFile.read())
        print(text)
        file = open("encodedClip.txt", "wb")
        file.write(text)
        file.close()
       #return it
    try:
        return send_file('encodedClip.txt', attachment_filename='encodedClip.txt')
    except Exception as e:
        return str(e)
```

The get route returns the entire clip as a base64 encoded txt file which is decoded in the central software.

Prototype Build Resources

The prototype system can be split into front end and back end:

Front End Build

The front end is built using a react native app with Expo components.

1. Install Expo: https://docs.expo.dev/get-started/installation/
2. Initialize project: https://docs.expo.dev/get-started/create-a-new-app/
3. Use map view api: https://docs.expo.dev/versions/latest/sdk/map-view/
4. Use permissions api: https://docs.expo.dev/guides/permissions/
5. Ensure the prototype app has a button which can send data via an API call to the main server. This is where the location data will be sent.
6. Implement design using Figma icons in the React Native app.

Back End Build

The back-end system is made up of multiple cameras to record the footage. Recording can be triggered remotely. Footage is then brought back to the server (whether automatically or manually). Footage is then automatically matched up against the location data which the app has collected to find the timestamps which dictate where the automatic edit must take place.

Camera Set Up

Any cameras can be added to the system. The essential point is that an Epoch time reading is taken when they begin recording which is how the footage can be matched up later.

A raspberry pi with pi cam was used as one camera. The pi must be Wi-Fi compatible.

1. Connect the pi to Wi-Fi (if using Eduroam use the following guide: https://medium.com/@TheMichaelClark/connecting-raspberry-pi-to-eduroam-wifi-quick-guide-cbea2c28d26b)
2. Install and initialise a Flask server on the pi: https://flask.palletsprojects.com/en/2.1.x/installation/
3. Use picam2/ picamera2 to write Flask API routes to command recording, stopping, and sending pi footage: https://github.com/raspberrypi/picamera2/tree/main/examples
4. Use python time library to note epoch time of starting recording: https://docs.python.org/3/library/time.html

A GoPro Hero 4 was also used as a camera for the system.

1. Connect Hero 4 to Wi-Fi: https://gopro.com/help/articles/block/How-to-Pair-the-Camera-with-the-GoPro-App?fbclid=IwAR2d_xqmcIdRE1XMKMUuP83p0I0H9O-bS8PllFN6mZSfeLkVtMXvpmqPZKs#HERO4BlackSilver
2. Then communicate via this API: https://github.com/KonradIT/gopro-py-api

Automatic Film Editing

To automatically edit the film, the main server uses the MoviePy library: https://zulko.github.io/moviepy/install.html

G. Appendix G – Usability Study Questions

Opening

How did you feel whilst using this way of recording?

How would you describe this way of recording to someone who hasn't seen it before?

What are the things you liked best about this way of recording?

What did you not like, or felt was lacking, about this way of recording?

Ski film can also be recorded with a GoPro or mobile phone. Do you feel that there is a difference between this way of recording and recording on a GoPro? If so, can you describe the difference?

User Experience

To what extent do you agree with the following statements?

	Strongly Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree

	Strongly Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
This way of recording would make my skiing experience more enjoyable.	○	○	○	○	○
Once fully implemented, I would use this way of recording on my skiing holiday.	○	○	○	○	○
This way of recording would be disruptive to my skiing experience.	○	○	○	○	○
Using this way of recording is less disruptive to skiing than using a GoPro.	○	○	○	○	○
I would use this way of recording as part of a group.	○	○	○	○	○
I feel like this way of recording lets me focus purely on the skiing.	○	○	○	○	○
I feel safer using this way of recording than other recording systems (GoPro, mobile camera).	○	○	○	○	○

Notes

Ease of Use

To what extent do you agree with the following statements?

	Strongly Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
The app seems simple to use.	○	○	○	○	○
I feel like this way of recording is easy to use.	○	○	○	○	○
It was clear how to start and stop recording.	○	○	○	○	○
It was clear how this way of recording worked.	○	○	○	○	○

	Strongly Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
I found it easy to know which buttons to press and when.	○	○	○	○	○
I feel like starting and stopping the app is a lot of hassle.	○	○	○	○	○
I feel like having to start and stop the app is worth the ease of recording.	○	○	○	○	○

Notes

System Status Visibility

To what extent do you agree with the following statements?

	Strongly Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
It is clear when the app is recording and not recording.	○	○	○	○	○
I felt that the map visualisation of where the recording zones are improved the experience.	○	○	○	○	○
I felt the map visualisation of knowing where I am and which way I'm facing, improves the experience.	○	○	○	○	○

Notes

App

To what extent do you agree with the following statements?

	Strongly Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree

	Strongly Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
The app looks clear and simple to understand.	○	○	○	○	○
The simplicity of the app design encourages me to use it.	○	○	○	○	○
I found the app layout unnecessarily complicated.	○	○	○	○	○
I felt I was able to learn and understand how to use the app quickly.	○	○	○	○	○
I feel like the layout of the app was suitable for purpose.	○	○	○	○	○
I have used my phone's internal sharing mechanism before.	○	○	○	○	○
Every sharing use that I would need for ski video is accessible via my phone's sharing mechanism.	○	○	○	○	○

Notes

Recording/ Cinematography

To what extent do you agree with the following statements?

	Strongly Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
This way of recording records every skiing aspect I would want it to record.	○	○	○	○	○
I would prefer more control over the final edit than the app offers.	○	○	○	○	○
I would prefer to have to do more work (editing, transferring footage) in return for more control over the edit.	○	○	○	○	○

	Strongly Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
I feel like the potential shots that this way of recording could record are too restricted (won't do moving POV shots).	○	○	○	○	○
I would rather have more resulting footage which likely captures all of the memorable moments, than less footage which only captured specific parts of the slope.	○	○	○	○	○

Notes

User Perception of Result

To what extent do you agree with the following statements?

	Strongly Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
I can see value in capturing skiing film through this way of recording.	○	○	○	○	○
I would use this way of recording as a holiday souvenir.	○	○	○	○	○

Notes

NASA Task Load Index

Please use the slider to answer the following.

	0	10	20	30	40	50	60	70	80	90	100
Mental Demand - How mentally											

	0	10	20	30	40	50	60	70	80	90	100
demanding was the task?											
Physical Demand - How physically demanding was the task?											
Temporal Demand - How hurried or rushed was the pace of the task?											
Performance - How successful were you in accomplishing what you were asked to do?											
Effort - How hard did you have to work to accomplish your level of performance?											
Frustration - How insecure, discouraged, irritated, stressed, and annoyed wereyou?											

Notes

H. Appendix H – References

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