WikUp – Quick learning in Augmented Reality using Wikidata

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Subject: Interaction Design (MAMM01)
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Abstract

Learning is something everyone has to do. Different approaches to facilitate the process of learning has been tried throughout history. With technologies such as Internet, and augmented and virtual reality there might be possibilities to devise new ways of learning. In this thesis I aim to explore an idea for such a new way of facilitation of learning, as well as exploring how to design for augmented reality with usability in mind. The work of the thesis can be divided into three parts. The first part consists of research and testing of different technologies and products (e. g. Hololens, Meta 2, Leap Motion, Windows Mixed Reality) to ascertain which would be most fitting medium available today to try to realise the idea on. In the second part a number of iterations of designing, creating and testing prototypes showing the basic functionalities of the idea are done. The third part is a final user test, carried out to evaluate the usability of the last iteration from the second part. The user feedback received in tests of all iterations showed that even the chosen medium might not be portable and mature enough to allow for a widespread adoption of the realisation of the idea in its current state. There was positive feedback about the idea in itself and its possible realisation with a more light-weight technology in the future. Received feedback also suggests there are some things to do, respectively *not* do while designing for augmented reality.

Keywords: augmented reality, Wikidata, interaction design, iterative design, Unity, Meta 2

Sammanfattning

Att lära sig saker är något alla behöver göra, och genom historien har det testats olika angreppssätt för att underlätta inlärning. Med teknologier som Internet, och förstärkt och virtuell verklighet kan det finnas utrymme för att skapa nya sätt att lära sig på. I detta examensarbete ämnar jag utforska en idé gällande ett sådant nytt sätt, samt utforska hur en kan designa för förstärkt verklighet med användbarhet i åtanke. Arbetet i detta projekt kan ordnas i tre delar. Den första delen innehåller utforskande och testande av olika teknologier och produkter (t. ex. Hololens, Meta 2, Leap Motion, Windows Mixed Reality) för att utröna vilken som är den mest lämpliga av de idag tillgängliga mediumen för att realisera idén på. I andra delen utförs ett antal iterationer av designande, skapande och testande av prototyper som visar idéns grundläggande funktionaliteter. Den tredje delen är ett slutgiltigt användartest, gjort för att utvärdera användbarheten av den sista iterationen från arbetets andra del. Användarfeedback från test av alla iterationer visade att till och med det utvalda mediumet kanske inte kan anses vara portabelt och moget nog för att möjliggöra ett brett genomslag av idén i dess nuvarande tillstånd. Positiv feedback erhölls rörande idén som sådan och en eventuell realisering av den med en framtida, mer smidig teknologisk produkt. Erhållen feedback visade också på att det finns vissa saker som verkar vara gynnsamma, och vissa som är mindre gynnsamma, att göra när en designar för förstärkt verklighet.

Nyckelord: förstärkt verklighet, Wikidata, interaktionsdesign, iterativ design, Unity, Meta 2

Preface

There are several persons that in particular deserves my gratitude for support and advice during this project.

Firstly, thanks to my supervisor Joakim Eriksson for good advice, helpfulness and giving me the freedom to explore my idea.

Secondly I want to thank my family for support, being there to discuss both methodology and my doubts as well as occasionally giving me a needed push.

Lastly, thanks to Malin. For considerable support, advice, discussions and for laying down the hard truths.

Munich, October 2018

Rasmus Olofzon

Contents

List of Acronyms

API	Application Programming Interface
AR	Augmented Reality
EEG	Electroencephalography
FOV	Field Of View
GIF	Graphics Interchange Format
HMD	Head-Mounted Device
HTTP	Hyper-Text Transfer Protocol
HUD	Heads-up display
IT	Information Technology
LAN	Local Area Network
LMC	Leap Motion Controller
LTH	Lunds Tekniska Högskola
MR	Mixed Reality
MVP	Minimum Viable Product
OEM	Original Equipment Manufacturer
RDF	Resource Description Framework
SDK	Software Development Kit
SPARQL	SPARQL Protocol and RDF Query Language
SUS	System Usability Scale
URL	Uniform Resource Locator
USB	Universal Serial Bus
VR	Virtual Reality
WMR	Windows Mixed Reality

1. Introduction

The facilitation of learning has long been a work in progress. The fact that humans learn new things all through their lives means that this is something that everyone must do. One might argue that the ability to learn how the world around us work and retain that knowledge in collective knowledge bases is in part what has enabled us to adapt to different environments and spread out over the globe.

With the breakthrough of technologies such as Internet, augmented reality and large digital storage there might be possibilities to further facilitate learning by new innovations with, and combinations of, these technologies.

My idea for creating a new type of facilitation of learning grew over time. Learning about the existence of Wikidata (see section 2.3) was a formative moment. Especially considering Wikidata together with the notion of a Semantic Web: also called a "Web of data" [1] [2], a Web where machines can read and understand data and which would, theoretically, allow for 'smarter' behaviour of web pages [3].

Furthermore, to an extent wikis like Wikipedia effectively enables a democratisation of knowledge [4], even if there are opinions that the implementation could be refined [5]. Lemke and Coughlin argues [4] that this should be utilised in teaching, alongside multi-modality and a few other concepts.

1.1 The Idea - on a conceptual level

The conceptual idea was that, when faced with a term, acronym etc that one does not know or remember the meaning of, one could perform a quick and easy lookup and get just enough information to be able to get the gist of the concept. This could then be used in a variety of

situations; when in a meeting at a new job, at a lecture, when reading
the instruction for a newly purchased product.

From this fairly general description one could implement the idea
in numerous ways. Due to this the first part of this project was an
exploratory phase, where I explored possibilities and decided on how to
realise the idea in the rest of the project.
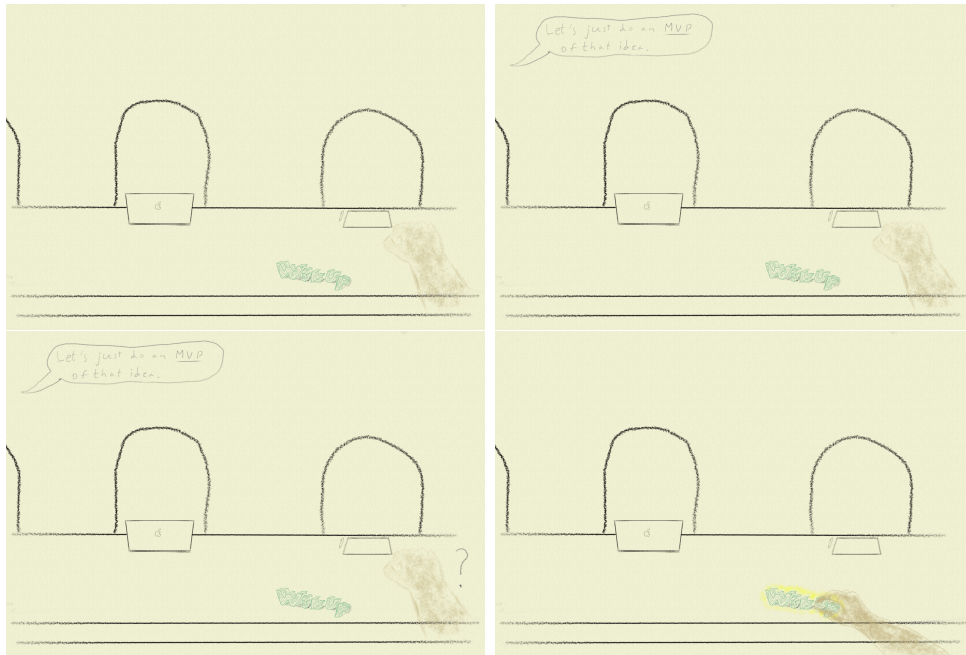
Figure 1.1: Sketches done to illustrate a use case for the idea. The user
sits in a meeting, a member of that meeting uses an acronym/initialism
the user does not know. The user initiates a lookup with WikUp by
touching the logo.

But, I jump ahead a bit. Let us look at a strong contender for the
form of the idea: using wearable augmented reality technology, like a
headset, 'smart glasses' or contact lenses. I will use some sketches that I
did during the course of the project, as a stepping board for explaining
the conceptual idea.

Take the example of participating in a meeting at a new job, prefer-
ably in a field you are not entirely at home in. Naturally, there will
be some use of words and acronyms that you do not know (see Figure
1.1). You could halt the meeting and enquire about what you do not

understand. This is, of course, easy to do and depending on the mentality of that particular workplace, welcome as a means of assessing your skills and knowledge as well as onboarding you. However, there could be things you believe that you 'should' know, the mentality of the workplace is such that questions are not rewarded, or that it is simply easier and faster for you to look up the information on your own compared to interrupting the meeting.

When you have initatied a lookup, or a wikup (see section 1.1.1), a view similiar to the one in Figure 1.2 would be shown. This shows a sort of information tree hanging in the air in front of you. The lower part in the images (or, the lower nodes of the tree) are different results from the wikup you just did. The higher nodes are which category or field the different results belong to. The rationale for this is that what you are looking for is often context-specific. You know if you are in the field of medicine or Java programming. One possibility is that your results will over time be tailored to the contexts you have chosen before.

The categories shown here are one level up from the results. However, it need not be limited to just one level, you could also traverse the information hierarchy up and down (more general concepts are located spatially higher in the tree). This could give you a better sense of and understanding of where the current concept fits into a bigger picture, which could help with the learning.

1.1.1   Etymology of the name WikUp

The name WikUp is essentially a combination of the words **wiki** and **lookup**. See section 2.1 for the word wiki. The reason for incorporating this word was that I chose to retrieve the information from Wikipedia and Wikidata. Furthermore, the central part of my idea was to perform quick lookups. When one performs a lookup against the wikis, a concatenation of that action would be to perform a wikup. It also doesn't hurt that wiki means quick (see section 2.1). Connotations can also be made to heads-up displays, HUDs.

From all of this, the name WikUp was born.
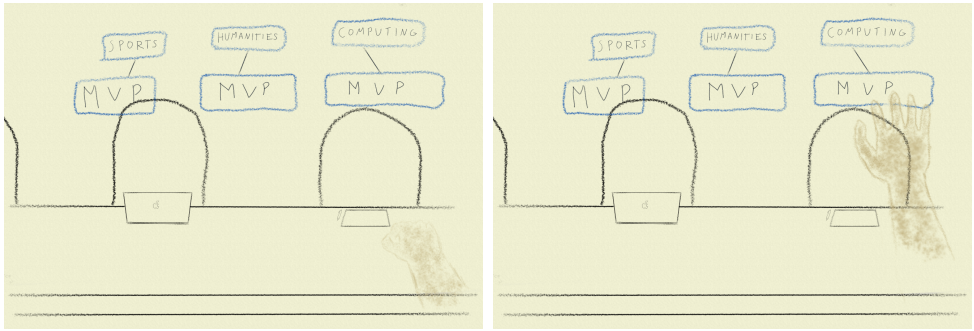
(a) Several uses of *MVP* are shown. The context for the meeting is IT, so the *MVP* in the *Computing* category is probably relevant here.

(b) The user selects this *MVP*.

(c) A short description together with an informative image is shown. The user hopefully has enough of a notion of the use of the acronym *MVP* in this context to participate in the meeting's discussion.

Figure 1.2: Some sketches to explain how a lookup (a wikup) can be used to retrieve a contextually specific explanation.

2. Technical Background

2.1 Wiki

A wiki is a web site that "can be modified or contributed to by users."
[6] The term was coined by American programmer Ward Cunningham
[7] in 1995 [6], and comes from the Hawaiian word for *quick* [8]. The full
name of Cunningham's technology is *WikiWikiWeb* (a play on WWW,
World Wide Web). His first implementation of the technology was as
a Unix program, and the name was in Unix fashion condensed down to
wiki [9].

2.2 Wikipedia

Wikipedia creators and founders James Wales and Larry Sanger used
Cunningham's technology when they built the first version of Wikipedia
[9] [10].

According to Wikipedia itself, it is a "multilingual, web-based, free
encyclopaedia based on a model of openly editable content." It is hosted
and owned by the Wikimedia foundation. [10]

2.3 Wikidata

"Loosely, you could describe Wikidata as Wikipedias database with over
46 million data items (April 2018)." explains Björn Hartmann [11]. An-
other explanation can be found in Müller-Birn et al. [12]:

> The Wikidata project aims to create a free, structured knowl-
> edge base that can be read and edited by humans and ma-
> chines alike. Wikidata has its origin in Wikipedia, the world's

largest peer-produced encyclopedia, with the particular purpose to manage facts represented in Wikipedia articles.

Wikidata is a *secondary database*, which means that it "records not just statements, but also their sources, and connections to other databases. This reflects the diversity of knowledge available and supports the notion of verifiability" [13].

It is probably easiest to explain the data structuring using Wikidata's web interface. This web interface is similar to Wikipedia's, in that one can search for different terms. A difference, however, is how concepts are represented and identified. The main identifier for a concept is a *QID*, a unique number prefixed by a Q [14]. E. g. the author Terry Pratchett has the *QID* Q46248 [15]. A *QID* "enables the basic information required to identify the topic the item covers to be translated without favouring any language." [14] The *QID* identifies an item. This item can then have *statements* that are in the form of key-value pairs. A visual explanation can be seen in Figure 2.1.
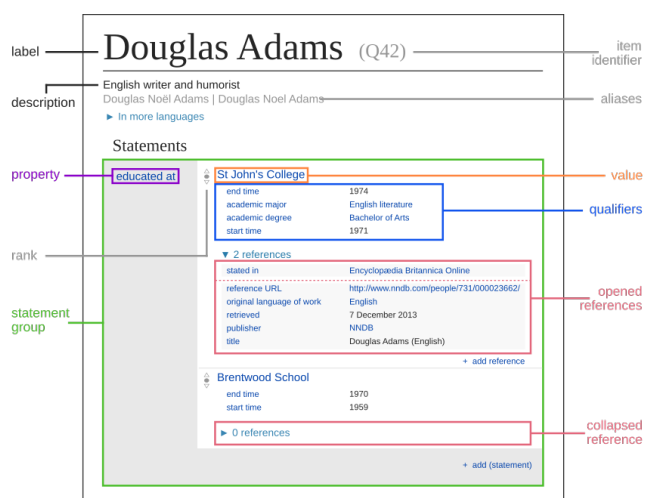

Figure 2.1: An image from Wikipedia explaining the web interface and the structuring of data on Wikidata. [16]

That is how the web interface looks. Of course, one of the points with Wikidata is that machines should be able to access and understand the information (like in the start of this section, about the Semantic Web). This is in part achieved by using RDF.

2.3.1 RDF

RDF stands for Resource Description Framework. It is a standard for the Semantic Web, defined by W3C. RDF itself defines a type of database different from the most widely known (relational databases), namely *graph databases* [2]. It uses **triples**, also called *statements*. W3C explains triples like this: "RDF extends the linking structure of the Web to use URIs to name the relationship between things as well as the two ends of the link (this is usually referred to as a "triple")" [17]. A triple consists of a **subject**, a **predicate** and an **object** [18] (see Figure 2.2).
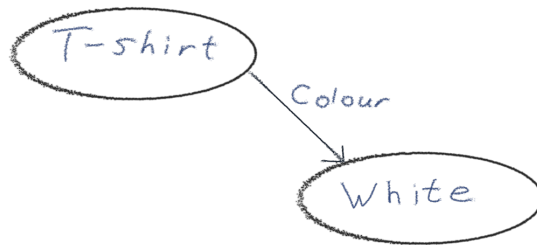
Figure 2.2: A simple explanation of RDF triples, using the example of a white T-shirt. The **subject** is the *T-shirt*. The **predicate** or **property** is the *colour*. The **object** is *white*.

2.3.2 SPARQL

SPARQL is a query language, and is pronounced like 'sparkle'. The tables of a relational database are queried by using SQL, and the triples of RDF data and its graph database are queried using SPARQL. SPARQL is a recursive acronym and stands for *SPARQL Protocol and RDF Query Language* [19]. There is a SPARQL endpoint to Wikidata, where one can also see example queries [20]. With the query language and Wikidata, it is possible to make queries such as '*Find all works of art where the title is an alliteration*' (this example and more can be found on the web page for the aforementioned SPARQL endpoint to Wikidata). There is a comprehensive tutorial on Wikidata on SPARQL [21].

2.3.3 Tools for working with Wikidata

There are a number of tools available for working with Wikidata [22]. Most relevant for this thesis is the ones "For programmers" [23], and especially the library `wptools`, written in the programming language Python [24]. It provides an easy programmatic access to MediaWiki instances (e. g. Wikidata). A basic example of usage is the one feature on the librarys GitHub README [24]:

```
>>> import wptools
>>> page = wptools.page('Gandhi')
>>> page.get_query()
en.wikipedia.org (query) Gandhi
en.wikipedia.org (imageinfo) File:Portrait Gandhi.jpg
Mahatma Gandhi (en) data
{
  aliases: <list(10)> M K Gandhi, Mohandas Gandhi, Bapu, Gandhi, M...
  assessments: <dict(10)> Pakistan, Alternative Views, South Afric...
  description: <str(67)> pre-eminent leader of Indian nationalism ...
  extext: <str(3077)> Mahatma **Mohandas Karamchand Gandhi** ( ; H...
  extract: <str(3372)> <p>Mahatma <b>Mohandas Karamchand Gandhi</b...
  image: <list(2)> {u'size': 2951123, 'kind': 'query-pageimage', u...
  label: Mahatma Gandhi
  length: 262,790
  links: <list(500)> 10 Janpath, 14th Dalai Lama, 1915 Singapore M...
  modified: <dict(1)> page
  pageid: 19379
  random: Salt
  redirected: <list(1)> {u'to': u'Mahatma Gandhi', u'from': u'Gandhi'}
  redirects: <list(53)> {u'ns': 0, u'pageid': 55342, u'title': u'M...
  requests: <list(2)> query, imageinfo
  title: Mahatma Gandhi
  url: https://en.wikipedia.org/wiki/Mahatma_Gandhi
  url_raw: https://en.wikipedia.org/wiki/Mahatma_Gandhi?action=raw
  watchers: 1,811
  wikibase: Q1001
  wikidata_url: https://www.wikidata.org/wiki/Q1001
}
```

2.4 Mixed reality

Many use Paul Milgram et al.'s definition of the realities, which is a continuum ranging from full virtual environments to real environment, called the Reality-Virtuality Continuum [25], see Figure 2.3.

Different products and technical solutions can be placed on this continuum in order to get a sense of to which degree they incorporate 'normal' reality and virtual reality.
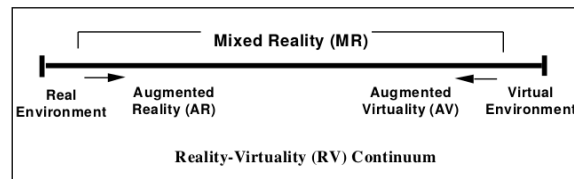
Figure 2.3: The Reality-Virtuality Continuum proposed by Milgram et al. [25].

2.5   Unity

Unity is a game engine and game development program [26], and it is commonly used for developing AR and VR apps [27].

2.6   Previous work

2.6.1   Wikitude

Wikitude is a product that has changed direction over the years: at the start the focus was on the *Wikitude World Browser App*, and lately the focus has changed to providing an SDK which allows for a broader use, more of something to build on (and with) when creating AR apps [28] [29] [30]. The first focus, the World Browser App, is what is the most similar out of the two to the idea this thesis is based on. The app runs on smartphones, and brings the user information based on their location and other phone sensor information. In a blog post Andreas Hauser of Wikitude explains it like this:

> Each place (or POI, Point Of Interest) belongs to provider, a so called "Worlds". Local Worlds are listed on strt-up [sic], each one providing information of places around you. E.g. check "Wikipedia" to see all Wikipedia information around you. You can then watch it in a List, on a Map or in the Cam (AR-View). [29]

It is more exploration-based, and allows one to find e. g. restaurants, historical information etc. [31].

2.6.2 Wikipedia visualisations

There are a number of interesting visualisations of Wikipedia and the relations on it. From sounds playing on edits or new user registrations [32] to being able to fly through a galaxy in space, where stars are Wikipedia articles [33] [34]. Several utilises mostly if a Wikipedia article links to another, mostly web pages [35] [36], one in VR [37]. A number of visualisations focus on the path(s) between articles, e. g. a web page that finds the shortest paths between two articles [38] or one that specifically finds a path to the Philosophy article [39]. There are also compiled lists of different visualisations of Wikipedia-related matters [40] [41].

3.   Method

3.1   Goals

- Explore the possibilities of the original idea

- Explore how interactions in AR can be designed in order to further usability

- Explore the integration of several MR techniques in order to simulate a more complex product.

- Produce a light-weight, non-intrusive, 'minimum viable product' prototype with good usability.

3.2   Structuring of the report

The work carried out in this project can be conceptually split into three different phases:

1. **Exploratory phase**

2. **Iterative development phase**

3. **Final user test**

The report will be structured according to these phases, and will thus be detailing the work carried out in as chronological a manner as possible. One thing this entails is that there will be no 'hard' separation between the text functions method, result and discussion. E. g. discussion relevant to one part of the Exploratory phase will be positioned at that point of the report, as opposed to broken out and placed in a separate Discussion header. Larger discussion about the project as a whole etcetera will, however, be placed under the Discussion header.

4. Exploratory phase

One of the first courses of action in the project was to decide upon which technology to realise the idea with. One natural constraint was which products were available in the Reality lab at Lund University, at which this project was carried out.

The products or technologies that were available and that I deemed suitable for realisation of the idea were:

- Leap Motion

- Virtual reality

    - HTC Vive
    - A Windows Mixed Reality headset

- Microsoft Hololens

- Meta 2

The choice of technology was influenced by e. g. ease of use, accuracy of tracking and suitability for the idea.

4.1   Leap Motion

The Leap Motion Controller (LMC) is a device that does hand tracking very well. It was originally designed to be used in conjunction with a regular computer [42], but the company has since switched orientation towards VR applications [43] [44]. They have created a mount for the LMC that can be attached to virtually any VR/AR headset [45], enabling the user to utilise the LMC's high hand tracking position instead of using a hardware hand controller. This was of course of interest for
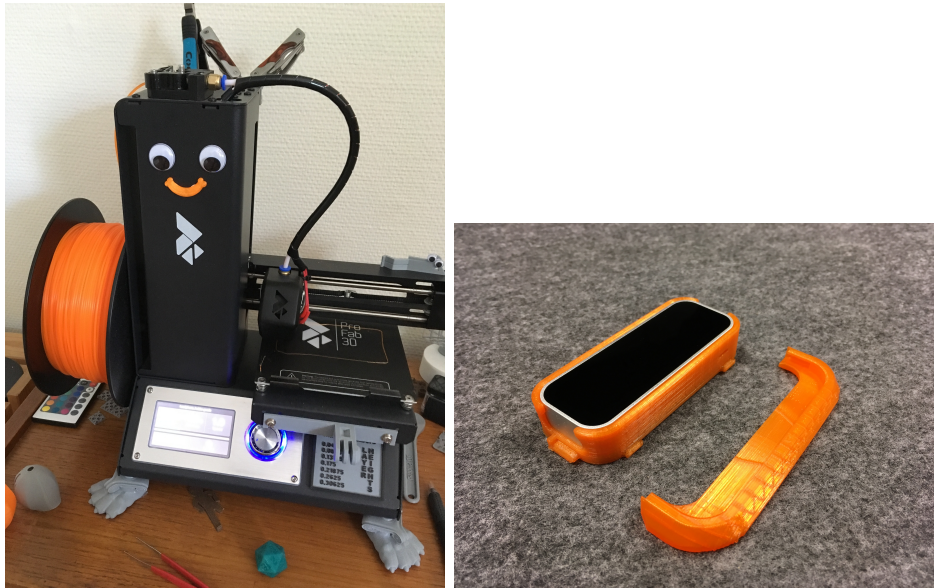
(a) My 3D printer, lovingly named Printie.

(b) The 3D printed Leap Motion Controller VR mount.

Figure 4.1: 3D printing the LMC VR mount.

my project. I found that they have released the 3D models for free [46], and since I have a 3D printer I printed it so I could try out the LMC with headsets (see Figure 4.1).

However, before I used the mount with any headsets I tested some desktop apps for the LMC to get a feel for how accurate it was, if it had any obvious limitations etc. My impressions were that it could track the hands impressingly well; even complex movements such as wiggling each finger by itself, or touching the fingertips of the thumb and individual fingers together were tracked well. One limitation was that since the LMC only tracks from one direction (from the device itself) any movements that were partially or fully concealed from it was, naturally, not tracked well (e. g. when the LMC lies on a desk, having your hand rotated fingers up and touching the fingertips of the thumb and individual fingers).

I was satisfied with the experience of using the LMC and its accuracy when tracking, so I proceeded to explore its use together with headsets. This will be described in the following sections about different headsets.

4.2 Virtual reality

One possibility was to realise the idea in virtual reality. This would naturally affect the way the realisation would work, e. g. considering the higher degree to which the 'real world' is present in augmented reality compared to VR.

4.2.1 Windows Mixed Reality

There are a number of Windows Mixed Reality (WMR) headsets available, from different OEMs (Original Equipment Manufacturer) such as Asus, Acer, Dell etcetera [47].

In the Reality lab there are several WMR HMD:s, I used an Acer-issued. The mount that I had printed for the LMC could have been attached with double-sided tape or something similar. However, I did not have any at hand at the time for testing, so I used a couple of rubber bands that I had. This did not make for the most good-looking setup (see Figure 4.2), but it worked for the testing purposes.
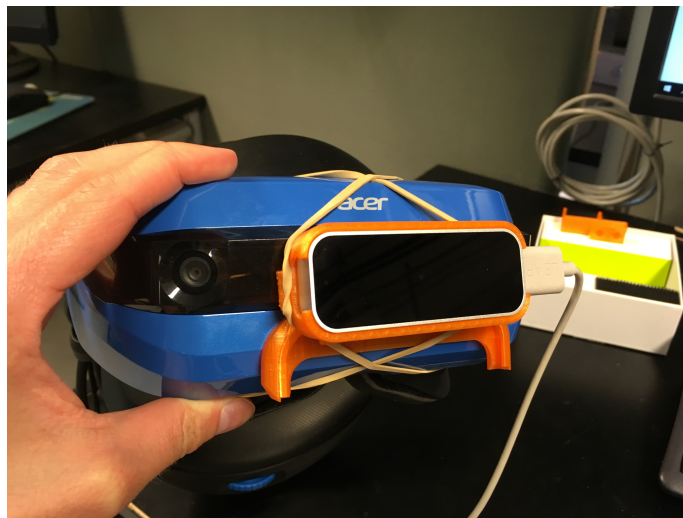
Figure 4.2: The LMC with the 3D printed mount, provisionally attached to the Acer WMR HMD with rubber bands.

I tested a few VR apps from Leap, most noteworthy is probably their 'showcase' app for VR use with the LMC: *Blocks*. [48].
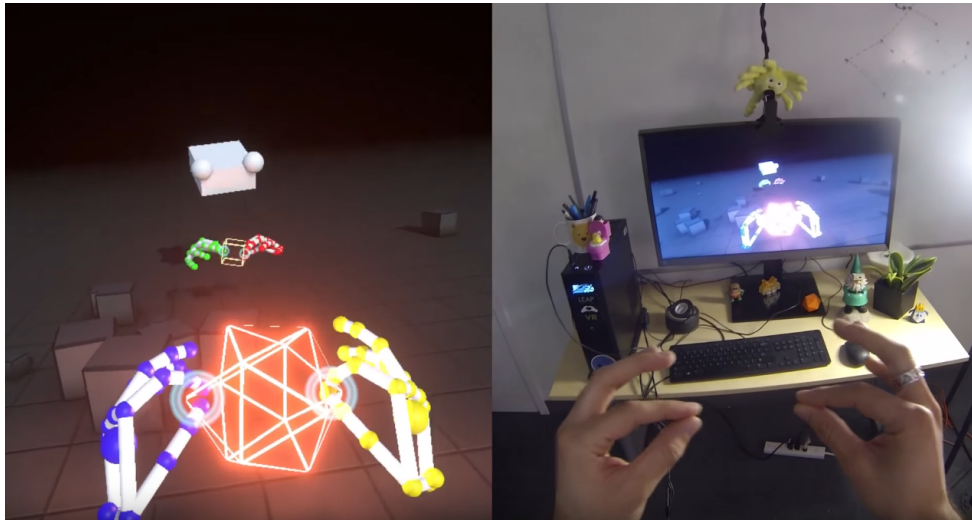
Figure 4.3: A screen shot from a video showcasing the LMC app *Blocks*
[48]

My impressions were that, firstly, some modifications would be needed
for this to work satisfactorily. Since the Acer HMD has an angled front,
the angle of the LMC was not orthogonal to the HMD and therefore the
hands tracking had an offset. This was noticed by the rendered hands
in the virtual environment being positioned a bit above one's actual
hands. This could be mitigated in two ways: writing a layer in C for the
LMC that accounts for the angle [49] or adding something physical that
adjusts the angle of the mount. I deemed it easier to take the physical
route, which I would probably have done by modifying the existing LMC
mount or modeling something of my own, 3D printed it and attached it
with double-sided tape.

A second impression is that, when the LMC was angled right the
hands tracking worked very well. The experience of using it was in
my opinion very positive, and would probably make for a more natural
interaction model compared to hardware controllers (like the ones for
the WMR HMD's or the HTC Vive).

Thirdly, the USB cable situation. The WMR HMD is tethered to
a computer for HDMI and USB connection, and the LMC must also
be tethered to a computer by USB. However, the included USB cable
for the LMC is short in a VR context when one stands up and moves
around. This hampers one's movement a fair bit. One solution to this

(suggested by my supervisor) would be to use a USB extension cable and wrap it around the WMR HMD's cables.

4.2.2   HTC Vive

The HTC Vive is another VR HMD, that uses two hand controllers and separate base stations used for tracking. There are two variants, the Vive [50] and the Vive Pro [51]. The tracking of the Vive is better than the WMR HMD's due to the Vive's base stations [52] [53] [54].

I did not carry out any testing with the Vive in this project. The reason for this being that I have worked with it in earlier projects and thus knew how it was to work with it. Therefore I mainly knew that it was an option to use in this project and that is also why it is only mentioned here.

4.2.3   About realising the idea in VR

Different ideas about realising the idea in VR was to create some sort of 'solar system', to show links between articles and perhaps incorporate some sort of gravity system that could be used to help understand different qualities, e. g. an article could be represented by a planet or similar astronomical body, and then more links to that article could give its representation higher gravity and therefore attract more of other articles. I found that visualisations of Wikipedia also utilising the metaphor of astronomical bodies already exists, for example the Wikiverse [55] (see Figure 4.4).

My supervisor, Joakim Eriksson, also told me about an earlier Master's thesis at the institution that visualised 'regular' web pages as a city inside a large sphere, carried out by Lars-Olof Rydgren [56], see Figure 4.5.

Ideas like these are certainly exciting. Further developing these or creating something inspired by these would have been, in itself, interesting. Furthermore, the medium of VR would probably have made this into even more of an immersive experience and thus given one a better sense of things like relation between articles, popularity of web pages or articles, etcetera. However, as exciting as these ideas are, they deviated from the idea and use cases I originally wanted to explore. I intended for this to be a tool that could fairly quickly give one a basic understanding of concepts and then to continue the ongoing work. That is,
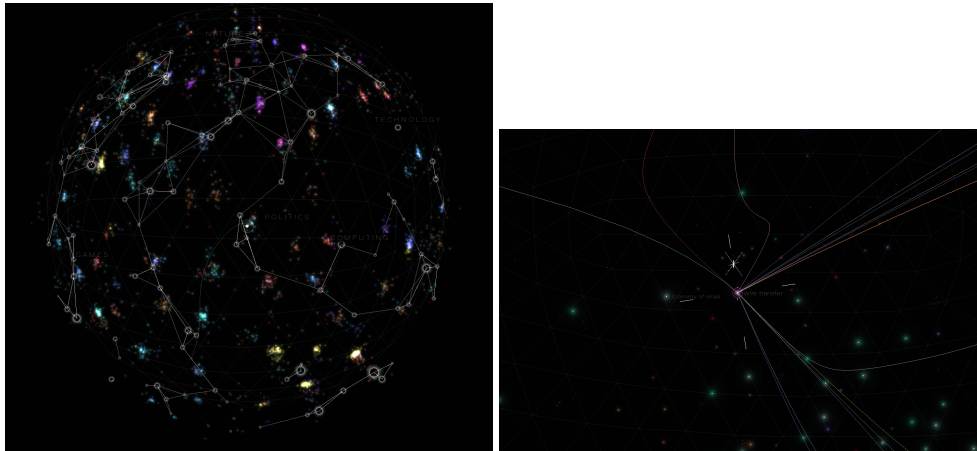
(a) Zoomed out.   (b) Zoomed in, and a link selected.

Figure 4.4: Screenshots from the Wikiverse web app.

more like a quick detour from one's main, bigger task, and this detour should help one in the main task. My assessment is that the lower degree of 'real world' presence in VR (and also the context change when one moves from the real world into the virtual one) would distract one too much from that main task. This makes me believe that using VR would probably be better for other use cases.

This was a perception that was formed over time, during my explorations of different headsets and products.

4.3   Microsoft Hololens

The Microsoft Hololens was a clear candidate for being the medium with which to realise the idea through. It is an AR headset from Microsoft [57] that is wireless and can be used without an accompanying computer. See Figure 4.6.

This HMD can track the user's hands and can thus also be used without hardware controllers. However, there are only two gestures that can be used: *Air tap* and *Bloom* [59]. The *Bloom* is basically only used to bring up menus, while the *Air tap* is used like a computer mouse click. This, and discussions with my supervisor, made me explore the use of the Leap Motion Controller (LMC) together with the Hololens.
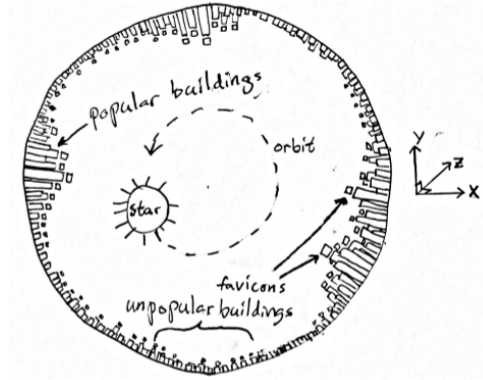
Figure 4.5: Conceptual sketch taken from Lars-Olof Rydgren's master's thesis [56], showcasing the shape of the world and that the popularity of pages correspond to the height of the buildings.

Figure 4.6: The Hololens. [58]

4.3.1 Hololens + LMC, take 1 (the American one)

I found one existing solution, by Zhengyi Luo, a student at Pennsylvania University [60] [61]. The instructions are outlined in the readme pdf in his GitHub page for the Unity Asset he has created [62]. Basically one uses the support in the LMC API for connecting to the LMC remotely, with WebSockets. So the LMC sends it data to the Hololens over Wi-Fi. On Windows one also has to add rules to the firewall that allows the traffic to pass through.

I got the streaming of LMC data to work, but did not experiment with creating something utilising the Hololens and the LMC together. The reason for this was the Internet situation in the lab. The desktop computers, which I worked on, are connected by Ethernet cable. The LMC is connected by USB to a desktop computer, it cannot be connected

to the Hololens directly (if so there would be no need for this Wi-Fi solution). The Hololens is connected by Wi-Fi. There is a Wi-Fi network in the Reality lab, unfortunately without Internet access (which I would need to query Wikipedia). The *eduroam* Wi-Fi reaches to the Reality lab and has Internet access. However, a device connected to this is not on the same LAN as the desktop computer I would be using. This would both be more insecure, opening up ports to the Internet (if this would even be allowed by the university IT staff), and it would also result in latency, which would impact the usability of the program negatively. I used a router in the lab to try and serve an own Wi-Fi to connect the Hololens to. But, to connect the desktop computer to the router I had to use the computer's only Ethernet slot, which effectively meant that I could not plug into the wall Ethernet outlet, rendering this solution without Internet access. A possible solution was to buy a Wi-Fi dongle to connect the desktop to the router in this way.

To conclude above discussion, a working solution to this problem could probably have been found. Possibly by downloading a Wikidata dump, the whole of Wikidata, and then querying this locally [63]. However, I decided to not use the Hololens. The reasons for this will be accounted for soon.

4.3.2   Hololens + LMC, take 2 (the Finnish one)

The second solution I found for using the LMC and the Hololens together was from a Finnish Master's thesis, by Nestor Köhler [64]. In it he attaches the LMC to the Hololens with double-sided tape and a 3D printed angling mount. Like Luo's solution, I chose to not use this. Partly due to the performance Köhler reports (e. g. an offset between actual and tracked fingers, which would "probably block implementing e.g. pointing and touching virtual objects" [64, p. 70]), and partly due to other factors which made me not choose the Hololens for realising my idea.

4.3.3   Impressions of the Hololens

One of the first things that I found obvious while testing the Hololens was its small field of view (FOV). In my opinion the immersion is broken time and time again by not seeing the whole of the virtual objects, and

makes the experience not much better than using an AR app on a mobile phone.

I did also not find the two gestures entirely intuitive, to me it seemed like one has to perform the gestures in certain ways (angling of the hand etc) in order for them to be registered reliably.

Placing objects was a bit cumbersome.

The quality that did give me a good impression was the room mapping. However, it seemed like that worked best with clean, basic geometric shapes. More complex shapes (chairs, people etc) did not get mapped great, and then the occlusions were a tad odd.

Another positive thing was the voice control. It could open up for nice interactions, especially for my use case of looking up terms.

4.4   Meta 2

Figure 4.7: The Meta 2 headset. [65]

The Meta 2 is an AR headset, developed by Metavision [66] (see Figure 4.7). It can track the user's hands for hand interactions, as well as map the room. Compared to the Hololens Meta 2 has a much larger FOV, is tethered to a computer and uses that computer's hardware for processing, and has no voice recognition. Since the Meta 2 uses an ex-

ternal computer for processing the graphics performance is markably better than the Hololens, which does its processing on an internal computer. There are not as many available apps for Meta 2 compared to for the Hololens, WMR HMD's or the LMC. I tried the apps made by Metavision for demo purposes, which included a 'Hands tutorial' which taught one how to grab and move virtual objects with one's hands. This also includes a selection of 3D models to view, as well as the possibility of mirroring ones physical display with a virtual one. One can also have virtual browser windows. With this I could set up a virtual multi-monitor setup with as many windows as I wanted, turn off the physical display and continue working with the computer keyboard and mouse in the virtual windows.

Other impressions of the Meta 2 was that it is quite heavy, and especially in the front part, which might not be the most ergonomic over time.

My experience with using the Meta 2 was much more positive than my experience with the Hololens. Using it also meant that I could circumvent the whole Internet situation with the Hololens, and the fact that the Meta 2 'natively' tracks the user's hands meant that I could have the kind of interaction I wanted without having to blend two different products together. That would of course have been interesting, but I prioritised my other goals higher.

4.4.1   Metavision design guidelines

Metavision offered guidelines on how to design for AR, supported by neuroscience articles [67]. These guidelines included advice such as: do not do any 'magic'. Here, magic is exemplified as having the user use a virtual magic wand, which when waved performs an action on an object not spatially near. In other words, make sure objects have an appropriate affordance. Other advice was: do not have more than level of nesting. They compared it to folders in a regular computer, which has several layers of nesting. Another advice: design 'real-looking' objects, and augment that with other modalities. E. g. a virtual paint brush that has its place in a virtual mug placed on a physical desk, when the paint brush is placed in the mug a 'clunk' sound is heard.

4.5   Conclusion from exploratory phase

After the exploring of different products, I chose to try to realise my idea on the Meta 2.

It was not an obvious choice. Arguments for the Hololens is its wider adoption and that it is from a larger and more stable company. The voice command possibilities of the Hololens would also have been useful in my idea. The Hololens also has better spatial mapping than the Meta. However, for my idea I would not rely on spatial mapping to a great extent.

Furthermore, my experience of the headsets' different FOV was that the Hololens's smaller FOV was detrimental to a user's experience. I also thought that the set of gestures available on the Hololens was limited, and with the Meta I would be able to utilise hand interactions more similar to the Leap Motion Controller.

5.   Iterative development phase

5.1   Design problems to solve

After deciding on the medium, it was time to start realising the idea. Firstly I identified key interaction points that would be in the program virtually independently of the design.

These were:

1. Initiating a lookup

2. Performing the search

3. Viewing the result of the lookup

4. Closing the result of the lookup / the program

I had different ideas of how to design these, both conceptually/technology-agnostically and dependent on the technology used.

Initiating a lookup

In adherence to Metavision's AR design guidelines (see section 4.4.1) one idea was to have a virtual object placed on a table (with the help of Meta's mapping of the room), hanging in the air or something similar. When the user touches or grabs that object a lookup is initiated. This object could be a number of things: a 3D logo for the program, a W, or a representation of some other physical object that would offer affordance. One idea is to use a model of a tree, which might help with the mental model of the category hierarchy as an information tree.

Performing the search

This point encompasses both specifying the term for the lookup and triggering a search for that specified term. For the term specifying, there are a number of different ways. The most available ones were to either search by voice or by keyboard, either a physical or a virtual one. Other solutions could be with a different type of keyboard, e. g. the Tap [68]. One could even imagine some other kind of input, either via eye tracking or controlled 'by brain' (e. g. through use of EEG (electroencephalography)).

For triggering of the search, that is more dependant on the design.

Viewing the result of the lookup

This is a very broad point. It includes things like:

- What information to display

- How to display that information

- Since I wanted to incorporate a category hierarchy:

  - How to display the hierarchy

  - How to traverse the hierarchy

  - What relations to use and show

Closing the result of the lookup / the program

Ideas for this is dependent on the Initialisation design, but if a virtual 'anchor' object is used (e. g. a WikUp logo or another object) an indicator on that object could be used to indicate the state of the program/lookup. One could then grab or touch the anchor when done with the program for now. E. g. the top of the logo opens, like a lid, at initialisation. When quitting the lid closes.

5.2   Storyboarding

In order to help me decide on design by getting some user data, I carried out some storyboarding. Two of the storyboards can be seen in Figures

1.1 and 1.2. I also storyboarded the closing of the program and traversing the hierarchy. These can be seen in Appendix A.

In these storyboards I did choose some versions of the design, in order to get feedback on them. E. g. I used a hierarchical information tree, where a higher, or more general concept, is positioned higher up spatially. I also used a basic WikUp logo as the 'home' of the program. There is also a possibility to 'fold out' nodes through touching an arrow on a node. I also used a 3D model of a tree as an anchor for the information tree, and the user quits the program by grabbing and dragging the tree and releasing it into the WikUp logo.

I showed these storyboards to a couple of persons, and I got feedback such as:

- It might be seen as 'socially dubious' to suddenly start gesturing in the air.

  - Especially during a meeting, and considering the use case where one wants to look up something that one 'should' know and therefore does not want to show that one does not, in fact, know.

  - On the other hand, if 'everyone' was using the program, this would be a non-problem.

- (From a person working as a management consultant:) "As a consultant, acronyms are often internal to the company." This showcases the problem with data not present in Wikidata, which is what I fetch data from.

- "In a meeting, only what the acronym [MVP] stands for is needed." Generalising, context should influence what information is shown.

- One should be able to set context right from the beginning, if one already knows one should not have to 'clutter' the interface with irrelevant information.

- Could add a possibility to save searches, in order to continue reading about them after the meeting.

- "If I look up and find MVP, I want to easily be able to find what 'prototype' means as well."

- There were also suggestions on different situations where this could be useful: in a lecture, studying at home, in a school environment, working on your own at a desk.
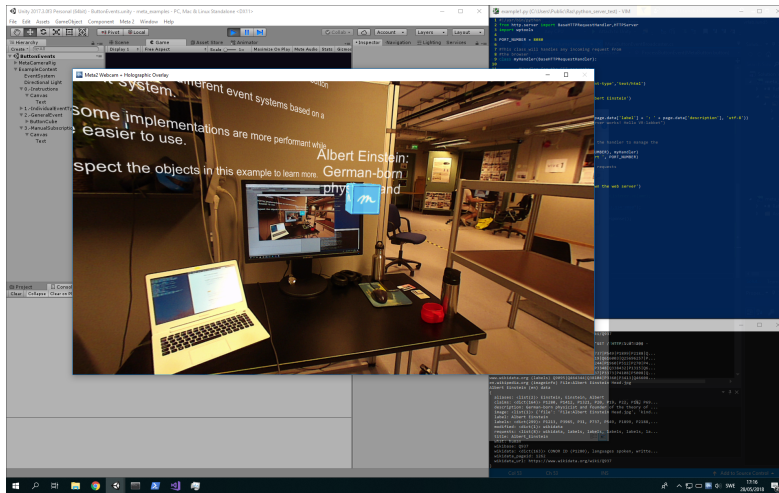
Figure 5.1: A screen shot of my proof of concept for the Python HTTP
server. (Note: I did not use Flask here, I later switched to that.)

The storyboarding was valuable in several aspects. For me, it forced
me to concretise my idea and highlighted some parts of it I had not
thought about how to solve before. It also, naturally, gave me some
feedback about how my idea would work and look like (which is easier
to do with images compared to explaining it in words), and gave me
some pointers about both my design ideas as well as implications of the
idea and the program.

5.3   Developing a hi-fi prototype

Since it is a bit hard to do low-fi prototypes for AR programs (which
my storyboarding effectively was), I started to implement a more hi-fi
prototype with the Meta 2. For this I used Unity (see section 2.5). For
fetching data from Wikidata I used Python and the module `wptools`
(see section 2.3.3), as well as the module Flask [69], to create an HTTP
server, which I could then send requests to from C# in Unity. This was
due to several reasons: I had programmed mostly in Python lately and
wanted to continue practicing that. It was also that I found the `wptools`
module with which I could easily accomplish what I wanted: search
programmatically on Wikipedia/Wikidata and select certain parts of
the result. I figured that I would have my hands full with learning how

to program for the Meta 2 anyways. I used the `WWW` class in C#, provided
by Unity, to send requests to my Python server.

A screen shot of my proof of concept for querying the server from,
and then displaying the result, in Unity can be seen in Figure 5.1.

I quickly realised that the full scope of my idea was not feasible to
implement during this project. Therefore, I had to make some compro-
mises and set some limitations on what I was going to implement.

5.4   Version 1 - the wooden board one

One of the first limitations was that I would not implement any 'start
the program' functionality, what I have described above could be done
by having a logo on the table and touching that to start the program.
Furthermore, at first I found no feasibly easy way to specify the term to
look up, so a limitation on that was to enter the term in Unity and let
the focus of the user interaction to be on viewing the result of a lookup
and exploring the category hierarchy.

This first version of course took the longest to develop, since I with
this built the foundation for the program.

Some screenshots of this first version can be seen in several figures,
the start of it in Figure 5.2. All screen shots are taken like this: the
Meta can send a video stream to the computer it is tethered to, and
when playing a scene in Unity a window appears showing this stream,
effectively mirroring what the user sees. Screen shots are then taken as
regular with said computer.

5.4.1   Features of version 1

Firstly, there were a number of features intended to work in this version:

Performing a lookup.   This was done by poking the text input field
(the white rectangle in Figure 5.2 with the text "*Enter search term
here..*"), which focused and 'selected' that field for text input. See Fig-
ure 5.4 for this. Text input was done by writing text on the physical
computer keyboard seen in e. g. Figure 5.3. This was not the origi-
nal plan (see earlier in this section), but I found out how to do it and
deemed that having the feature to specify a term during runtime, even
if not in the best conceivable way, was preferable to not being able to

Figure 5.2: The view from the Meta 2 HMD at the start of the first version of WikUp. The picture is taken as a screen shot at the computer the Meta is tethered to, of a window which fed a stream from the Meta's cameras.

Figure 5.3: This showcases the built-in indicator for when a grab is possible: a blue donut shape appears at the back of one's hand. When grabbed the donut is filled in and becomes a full blue circle. When released, the circle becomes a donut again, and when out of reach (outside the collider) the donut disappears.

do it at all. The lookup was triggered at an 'Enter' press at the physical keyboard. *(Note: this functionality relied on the Meta's Virtual Mouse feature, mentioned in section 4.4. This feature could be turned on and off by pressing `F8` on the physical keyboard, which hid and showed the virtual mouse. I simply hid the virtual mouse at all times. This, however, meant that sometimes the keyboard would not register written text because the feature was turned off, which meant that one had to push `F8` again to activate it.)*

Moving the panels   One could move both the base node (which I will also call root node) and the rest of the nodes. This was achieved by grabbing the white handle of a panel. There is a difference between the (1) case for the root node and the rest (n) of the nodes: moving a non-root node only moves that individual node. Moving the root node moves the whole node tree. (It was also possible to move the WikUp logo. This only moved the logo.) In Figure 5.5c a non-root node is being moved.

Exploring parents   The spheres on top and on the bottom of the panels (black spheres in Figure 5.2): the intention was for them to, if the looked-up term has parents or children, become red. This was meant as an indicator that they were interactable and that one can get more information by interacting with these. I will also use '*fold in*' and '*fold out*' parents/children for referring to this functionality. The use of the terms 'parents' and 'children' here means utilisation of the `subclass of` property on Wikidata for the 'parents' of a term. E. g. in Figure 5.5b the term 'dog' has parents, aka is a subclass of, 'domesticated animal' and 'pet'. The fact that this term has parents turns the 'parent sphere' red. As for the 'children', this was a tad harder. There was no property on Wikidata for e. g. *superclass of*. My plan for that was to utilise SPARQL and find all QID's whose `subclass of` property matched the one for the looked-up term in WikUp. This would then be the children of the lookup term. The reason for this functionality not being included is that I spent some time endeavouring to make that work, but did during that time not find a well-working module. In hindsight, I could have written something myself that formed a query in the query string part of a URL included in a HTTP request to Wikidata's endpoint. During the time I worked on this there were other, bigger problems that I felt I had to solve in order to make this version usable. Thus I 'saved' this

Figure 5.4: Selecting the text input field to enable writing with the keyboard.

functionality for later, but still kept the sphere on the panels since the indicator still worked for parents and subsequent parents of the root node (even if one could not 'fold in' their children). This functionality can be seen in both Figures 5.5 and 5.7.

5.4.2   Design decisions for version 1

Here I will discuss why the design, both visual and regarding interactions, is the way it is.

Firstly, the 'wooden board' stylistic of the panels. This is because I wanted to follow the design advice of Metavision (see section 4.4.1) to design virtual objects so that they are similar to real-world objects. At first I had the panels simply coloured grey, and partly to make it look better while I was developing I exchanged the grey colour for a wooden board texture. For the handle I found a cotton texture to make it look like it was bound with coarse cotton thread. I enjoyed that stylistic, so even if that was not strictly mapped to a certain real-world object, it still had a 'real-world feel' that I liked. At the same time I had not gotten all features I planned for this version to work, so this wooden style sort of stayed on.

The parent-child spheres were also a sort of work-in-progress that stayed on due to 'larger problems needs attending to'. They came from sketches I made when planning this version, specifically from the sketch in Figure 5.6a.

I had a couple of different ideas for the movement of the tree. They can be seen in Figure 5.6c. One was to have a stationary 'control board', positioned to a real-world surface utilising the spatial mapping of the Meta. One would then move the tree by some sort of joystick on this
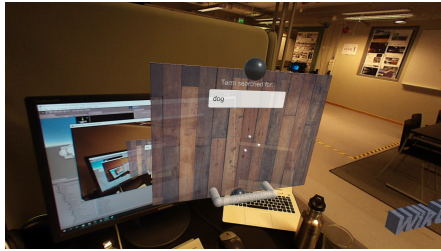
(a) When a lookup is triggered, a 'hold on' symbol consisting of three spheres rotating around a point is shown.
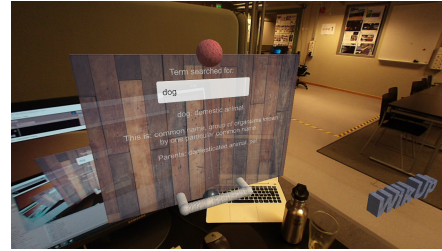
(b) How search results are shown, exemplified through a lookup of the term 'dog'. Notice that since the term has parents, the top sphere has turned red.

(c) The parents of *dog* folded out the upper left node grabbed.

Figure 5.5: Showing a lookup in progress.

board. The second was that moving the root node moves the whole tree. The third was to have a miniature model of the tree, and moving this miniature moves the full-size tree. One of Meta's guidelines was 'no magic' (see section 4.4.1). This entailed that no strange, non-obvious behaviour should be attached to objects and that an actuating object should stay spatially close to what it is actuating. Considering this, the second idea was best. I liked the third as well, it would be good to have an overview of the tree (the miniature would update with the full-size tree) and if/when the tree grows larger (many parents or layers of parents) it can be hard to move the whole tree. But, I deemed that the guidelines were prioritised, making the second idea the chosen candidate.

Regarding the text input field and the text input model: this is, as stated above, not the best conceivable solution. This mixes the old desktop metaphor of windows, text fields and mouse clicking by the 'poke at the text field' functionality. A better solution would be e. g. voice

control. This would have been easier with the Hololens. It could be doable here as well, with an external microphone. However, this would have taken time to figure out how to do and integrate with the rest of the system, and it was not in line with what I prioritised for this project. One could also imagine a kind of virtual keyboard, but I did not think it the best idea. Partly because it would probably take longer time than using the physical keyboard and partly because it would still preserve the desktop (or, in this case, the typewriter) approach.
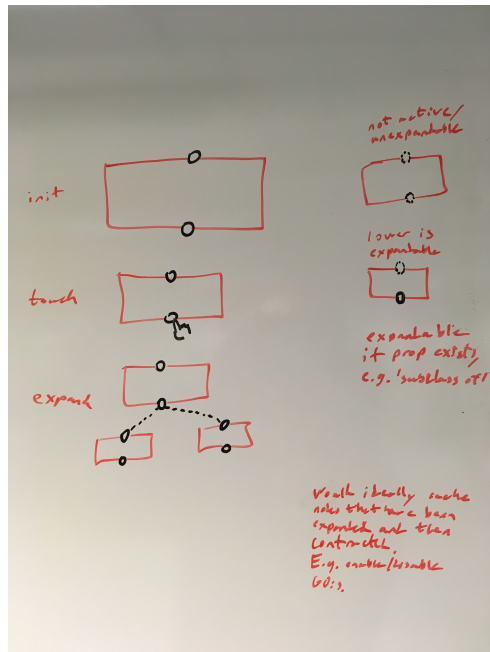
(a) This is about the folding of parents. To the left is the behaviour when expanding a parent/child relation, to the right is the indicator of states for the relations.
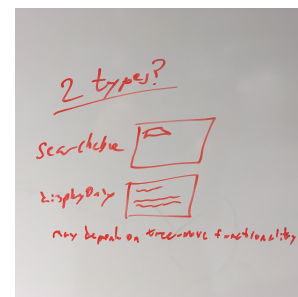
(b) This is about the separation of root and non-root nodes.
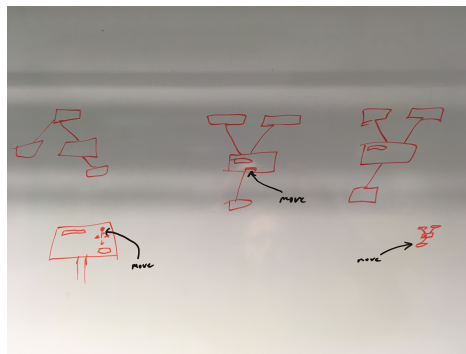
(c) This is about different ways to move the whole tree. Left: a stationary 'control board' controlling movement with a joystick. Middle: root node moves whole tree. Right: Miniature version of tree moves whole tree.

Figure 5.6: Sketches I made when planning Version 1.

5.4.3 Formative tests of version 1

I let three persons test this first version. All were engineers or engineering students. The process here was for the participants to use the think-aloud protocol. I will outline feedback from the three participants seperately.

First participant

Engineering student, 26 years, third year.

- The panels have fairly 'hard' edges, make them more 'soft'

- "Why the wooden texture? The handle makes the whole panel reminiscent of a toilet seat lid."

- "The panels were a lot 'in your face'. Make them smaller, proportional to the text on them. Now there is a lot of unused space on them."

- There was confusion over the "This is: .." field, namely the Wikidata property 'instance of'. What that really entailed.

- "Should not have the redundant label in the search result field, one can see at the top what one has searched for."

- The selecting of the text input was obviously not intuitive or easy to use even when told how to do it. I noticed that as well, sometimes the 'click' would not trigger before one's hand was almost fully through the panel. The participant tried punching the input field and poking the whole panel. Also not intuitive that it worked better to 'click' with one finger.

- For the Meta to register and track ones hand, it works best if it sees the back of one's hand. That was not (of course) not transparent to a user. A more common position is to have the hand slightly rotated compared to orthogonal to the headset.

- "The 'parent' panels look to similar to their child, hard to tell them apart."

- Asked for a better distinction of the term one has searched for and the information retrieved as a result of searching for that term.

- Saw the parent-child spheres and said that it reminded them of a planet, apparently got inspired and gave the idea that the relations and nodes should be shown similar to "a solar system" or "molecules".
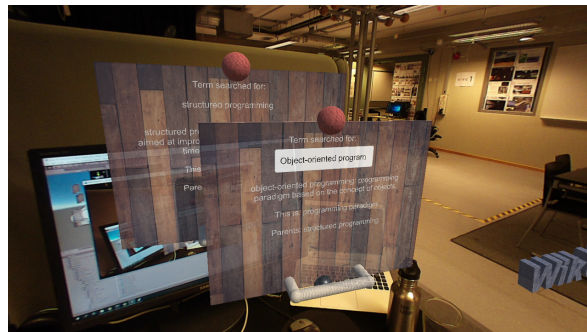
(a) A search for *Object-Oriented Programming.*

(b) Parent of *Object-Oriented Programming* and subsequent parents folded out. This figure shows the hierarchy from afar.
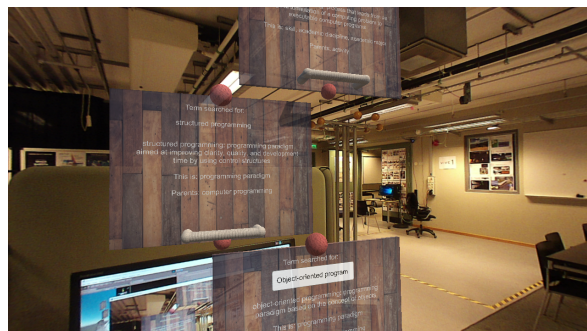
(c) The hierarchy close up.

Figure 5.7: Showing folded-out parents, several of them.

Second participant

Engineer, 30 years, working with software development and usability.

- Confusion about which was the root node.

- Related to above point, confusion about which nodes were grabbable, and why the root node moved *all* nodes.

- Tried to, and verbally expressed a want to, 'draw' the parents out of the parent sphere. A design proposal to exchange the sphere for a miniature representation of what one will get if interacting with the object, in this case miniatures of the parent panels that would spawn upon grabbing the object.

- Here as well there was confusion about the interaction model of the Meta HMD:

  - Held their hand upside down when grabbing, which did not work very well (let me re-iterate that the hand tracking works best when the back of the hand is held orthogonal to the HMD).
  - The selecting of the text field (the 'clicking') was not intuitive for this person either. Confusion about having to press 'through' the panel for the click to register.
  - Not transparent that the HMD needs to have one's hand in its FOV for it to track.

- Spoke about being able to "place earlier searches behind oneself", basically saving searches by spatially moving the panels related to that search to another location, to have a sort of 'search history'.

- Asked for lines connecting the nodes, to give a sense of the hierarchy.

- (After testing the program:) Discussed skeumorphism [70]. Said that it can be a good idea, but also warned that it can be limiting; a known object has its properties and interaction possibilities, or affordances, it might prove hard to extend that functionality in a sensible way.

- (After testing the program:) Urged that it can be warranted to be "extremely obvious" in one's design, more so than one can think. It might be needed for the user's to understand the designer's intentions.

- (After testing the program:) Spoke about identifying what the users' most common action is in the program and making sure that is as simple and easy as one can make it. This advice is similar to 'identifying red routes in one's design' [71].

Third participant

Engineer, 26 years, working with optics and software development. It was soon obvious that this person was used to the think-aloud protocol, and good at it. This was due to the person halting before taking actions to verbally state their hypothesis of what different things represented and what the outcome of different interactions would be.

- (During Hands tutorial:) "The feeling of depth is not great", referring to a disparity between where their perception of the virtual objects told them where the objects were and where the virtual objects actually were.

- Also had trouble with selecting the input field.

- "It's an uneccessary step to always have to select the input field, it would be better to have that always focused so one just had to write on the keyboard."

- (While trying to find info about parents:) Tried to touch the word 'parents' on the panel. Poked input field, which did not register.

- Wanted similiar functionality to parents when there is a 'disambiguity page', so one could select the meaning one is looking for.

- "The first image on Wikipedia should also be shown."

- Confusion about that some terms listed as parent or instance of could not be found when performing a search on them.

- Thought it would be nice to display 'Not found' terms similar to Wikipedia, with red text.

- "Not a obvious difference between 'This is' and 'parent'."

- "It would be nice if there was a button or similar for 'This is' so one could explore that property as well."

- "The parent and 'this is' nodes could spawn directly instead."

- Tried to 'draw out' parents from the sphere instead of just grabbing the sphere.

- Tried to grab the edges of the panel and resize it.

- Tried to expand parents when sphere was black. Confusion since the Meta 'blue circle' showed up as indicating that the object is grabbable.

- "Don't seem to be able to fold in the parents, so I guess that I should just put them over here" and proceeds to move individual parent nodes.

- Understood after some testing that the moving the base node moves the whole tree of nodes.

- Folded out parents as long as it was possible, "I've arrived at 'entity', hard to find more parents now..". "It's nice and fun that one can explore the hierarchy, but it's cumbersome that the number of nodes quickly escalates, would have been better to have one node that one can go back and forth in. Or, everything could scroll up and down."

5.4.4   Conclusions after version 1

One thing that was obvious was that much of the feedback I received was not really about my program and design. For at least two of the participants this was the first time testing an AR headset, which is an effect that certainly has an impact. Furthermore, the Meta headset hand interaction takes some getting used to. Not overly much, but it takes an amount of time just to learn that the hand tracking works best when the HMD can 'see' the back of one's hand and that a blue donut shows up when objects are grabbable and that that donut is filled in to become a full blue circle when one grabs an object. Furthermore, the 'desktop/AR' hybrid of having a text input field on a virtual object, and especially since the selecting of that works suboptimally (one has to press 'through' the panel), is absolutely an ideal solution. I tried to tweak parameters for the input field so that the trigger zone would work better, but could not seem to make it much better.

The use of 'real' objects (aka skeumorphism) should be used with care. In order for that to be justified one needs to use a metaphor that aids in the understanding of the mental model. For the next version, change the wooden panel stylistic.

I needed to clearly differentiate between the root node and others.

I should improve the 'fold out parents' object, either a smaller version of the nodes or something else.

It was not easy to understand the 'instance of' and 'subclass of' properties. That works well just for certain terms, is also not intuitive or used by most people (compared to e. g. software developers).

Furthermore, what information is actually shown as a search result could be improved. For different searches/terms one might argue that

Figure 5.8: What is shown at the start of version 2.

different kinds of information is wanted.

The 'desktop/AR' hybrid of text fields on AR panels and the use of a computer keyboard is not the best solution.

There was some confusion about earlier nodes not disappearing. This was a bug in this version that I had not solved yet, the idea was for the user to be able to fold out and fold in the nodes.

There were also several good suggestion for features, most of them which I knew that I unfortunately would not have time to implement (see discussion in section 5.3).

5.5   Version 2 - the blackboard one

For this, I decided to scale down and mostly evaluate another design for the nodes.

5.5.1   Features of version 2

The start of version 2 can be seen in Figure 5.8. There is one node, the root node. This is styled as a blackboard.
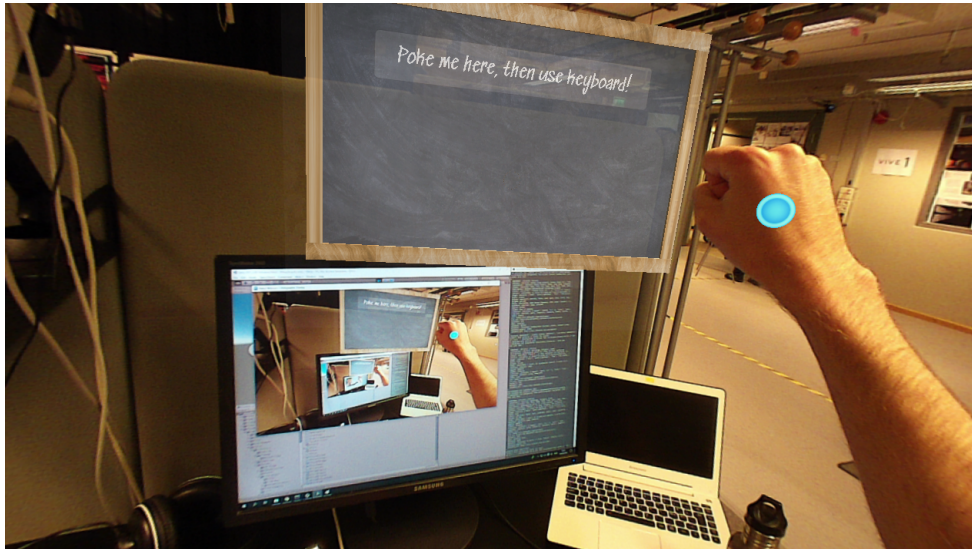
Figure 5.9: This shows how one grabs the node when moving it.

Performing a lookup. This is done much in the same way as for version 1: one pokes the text input field (which now is updated with the text '*Poke me here, then use keyboard!*' for clarity) and then uses the physical keyboard to specify what term to look up. The lookup is, again, triggered with the 'Enter' on the keyboard.

Moving the panel. In this version there is only one panel, the root node. This is moved by grabbing the node by its wooden frame, as can be seen in Figure 5.9.

A new addition to this version is that when the user looks up '*jogging*' a 3D model of a humanoid doll appears, see Figure 5.10. This model is moving and is jogging.

5.5.2 Design decisions for version 2

I wanted to continue the real-world similarity. This time I used a concrete real-world object, which was first suggested by my supervisor: a blackboard. The rationale for this was that is suggests learning as well as interaction with it. We discussed the possibility of using a virtual chalk for writing on the board (this would also be in line with Metavision's design guidelines), but making that work properly could prove to result in a work load justifying a master's thesis in its own.
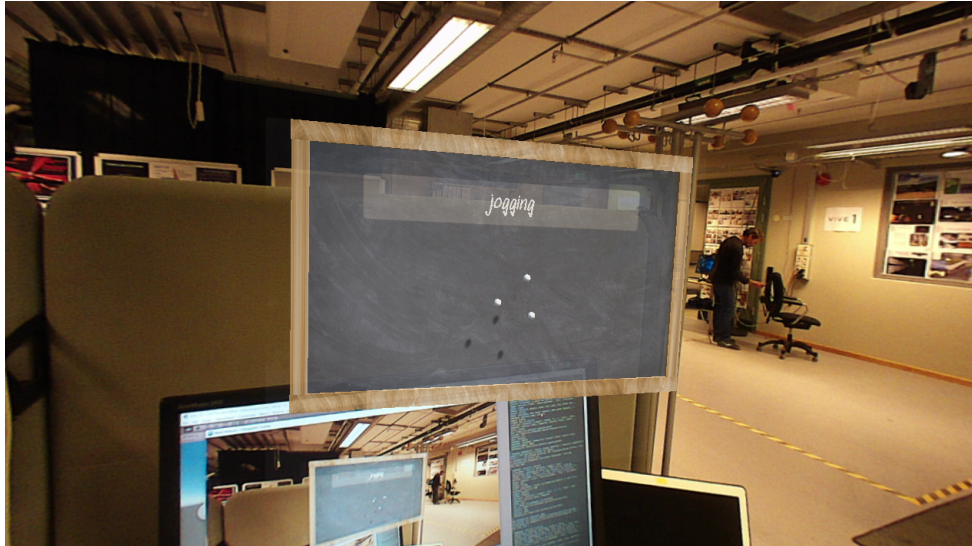
(a) A lookup has been triggered, and the waiting symbol (the same as in version 1) is spinning.
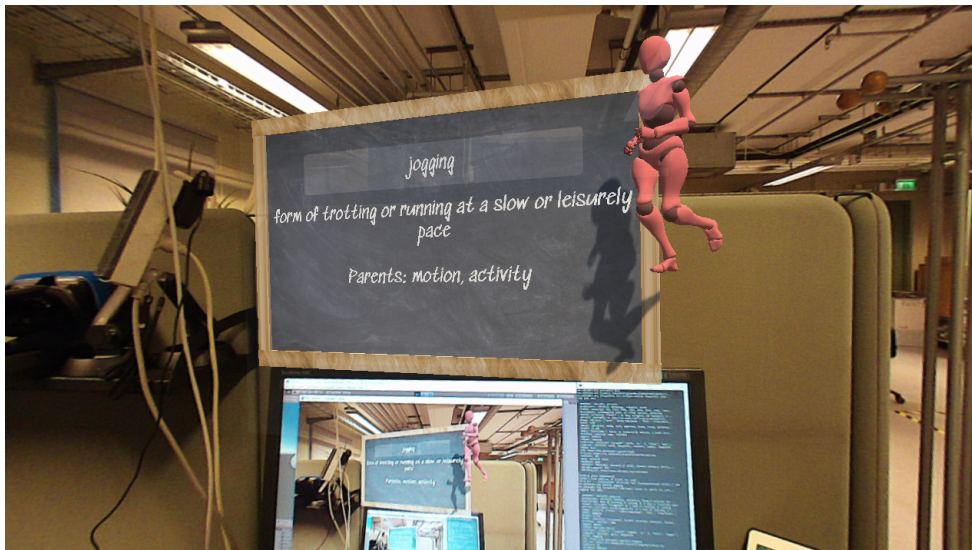
(b) This shows a result of a lookup in version 2. Especially noteworthy here is the 3D model of a jogger, which is moving and performs the act of jogging.

Figure 5.10: This shows a lookup in progress.

I used no handle for grabbing the node in this version. This was because I researched common designs of blackboards (read: googled pictures of blackboards) and found no *de facto* standard for handles. This is probably due to the fact that blackboards are usually mounted to a wall or on a movable rack. My hypothesis was that since the frame does not offer any obvious affordance about being grabbed, users might have a hard time understanding how to use this feature (*Moving the panel*). On the principle that the testing of one's hypotheses is healthy, I kept the feature the way it is.

The inclusion of the jogger 3D model was very much in line with my original design. One thing I imagined was that on lookups, explanations in appropriate mediums would appear alongside a textual description. This could be a 2D image of a person (or, for that part, a 3D model of a person) or a painting, a 3D model explaining something hard to show in two dimensions (e. g. a Möbius strip) or something moving or intricate (like how to use a certain tool, how to knit, a construction technique for a bridge). It could also be a short audio clip for a piece of music or a certain kind of sound.

The absolute preference would be for this kind of medium to be retrieved automatically. However, during my (short) search for this kind of thing I did not find anything suitable. One could imagine a kind of API with open and free 3D models, which one could query programmatically depending on the term a WikUp user has specified, and automatically include and display the response 3D model. There are several problems here, though: firstly, the existence of such an API. Secondly, I am unsure of the possibility of automatically and programmatically including 3D models in Unity. As for the first problem, one contemporary possibility would be to make a web scraper that went through a number of 'regular' web pages (e. g. Thingiverse, Youtube, NASA's 3D models etc.) and retrieved the links for media corresponding to the specified query. Alas, again, time and priorities made me focus on other things. Perhaps this kind of thing will be easier with the Semantic Web, if that emerges in the future.

Another possibility would, in hindsight, have been to include any eventual pictures found on Wikipedia. The links for these were retrieved with `wptools`, so including them in the panel would not have been difficult to do.

In this version of WikUp, there was only one 3D model; the jogger. I wanted to evaluate the impact of that before I spent mantime manually

searching for and importing more models into Unity.

5.5.3 Formative tests of version 2

First participant

Engineering student, 26 years, third year (the same as in the tests of version 1).

- Had trouble grabbing the blackboard, not obvious that one should grab the frame (which was my hypothesis).

- "The blackboard gives one the association of learning things, but is also a bit boring. Don't know what one should have instead, though. Again, solar systems!"

- Confusion about the purpose of this feature-limited version. "You should write about the purpose of the program in the instructions."

Second participant

Engineer, 30 years, working with software development and usability (the same as in the tests of version 1).

- "I like the jogger! More searches with moving models!"

- "One thing that would work well in AR is to explain phenomena that are hard to explain." Proceeded to speak about a GIF they saw explaining how a key works, which made the purpose of the cuts very obvious. "Do the same with 3D models, for example explaining how a motor works or something."

- Spoke about the social aspects, "sitting in a meeting and poking the air might be considered weird. Of course, would work if 'everyone' used it."

- Suggested a 'details' button that would give more information if one needs it.

- Thought that the text input field worked reasonably well, especially considering that people "know that from other programs". Pointed out that a virtual keyboard would be even more cumbersome. Suggested voice control.

5.5.4   Conclusions after version 2

It would probably be better to have something obvious to grab onto to move panels (which also was my hypothesis, but I wanted to test it).

I should write some information about the purpose of the program in the instructions for the user tests.

More 3D models would be great.

The blackboard as a panel stylistic was perhaps not the most optimal choice. However, I had a hard time thinking of something better that balanced the real-world stylistic and a nice visual design.

5.6   Version 3 - the natural one

5.6.1   Features of version 3

Performing a lookup.   This is done very similar to the earlier version. One pokes the input text field to 'select', or focus, it (see Figure 5.11c) and then uses the physical computer keyboard to specify the lookup term. 'Enter' to trigger lookup.

Moving the panel.   This is done by grabbing the brass knob on the panel (can be seen in Figure 5.11b). In this version only the root node can be moved. This still moves the whole node tree.

Exploring parents   This is indicated by a new object: a model of a tree. When there are no parents, it is not shown at all. This looks like in Figure 5.11. The same model is used for both when parents are expanded and contracted, the difference being that when contracted the tree is scaled down in the horisontal dimensions, making it appear narrower. See Figure 5.12a. There is also attached a particle system to it, which emits small green spheres from it. When the parents are expanded, the tree model is also expanded to its normal, fuller size. See Figure 5.12b. In this version it is not possible to expand parents' parents.

5.6.2   Design decisions for version 3

After the feedback of version 2 I added an object to grab for moval of the node. I styled this as a brass knob. I did this because from
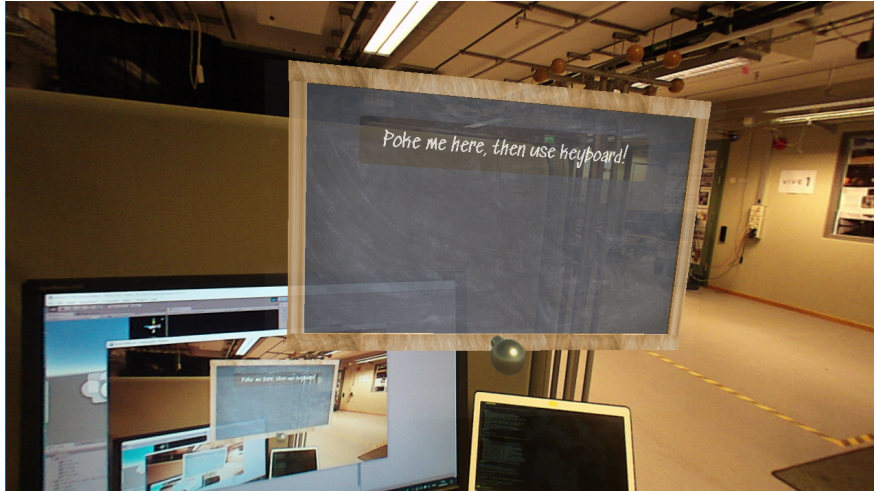
(a) What is shown at the start of version 3 of WikUp.
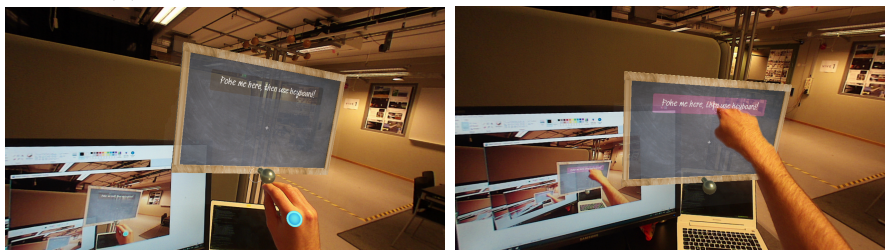
(b) Grabbing the root node to move it.

(c) Selecting the text input field by touching it. When the 'click' triggers a sound is played and the field flashes red.

Figure 5.11: Start of version 3.
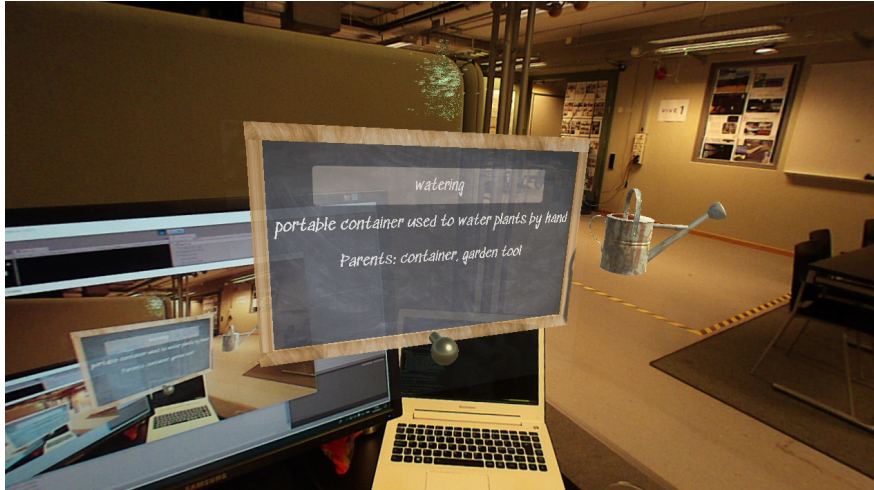
(a) The result of a lookup on the term 'watering'. A 3D model of a watering can (which the result of 'watering' yields) is shown to the right. Notice the updated 'parents are available' model which is on top of the panel. This is a small and narrow model of a tree, which has a particle system attached (which looks like small green spheres emitted from the tree).

(b) When the parents of 'watering' has been folded out. Notice that the 'parent' tree model on the root node has been expanded into its full size, and the particle system is turned off.

Figure 5.12: Showing how the results of a lookup can look in verison 3.

(a) A close-up of the panel. Here one can see even more clearly that when the parents are expanded, the indicator is more thick.

(b) This is another 3D model added to version 3; the Earth. This model rotates slowly around its axis, clouds are animated on its surface and one half of it has daylight and the other half has night.

Figure 5.13: More screen shots from version 3 of WikUp.

my observations and experience with the Meta, to grab like one grabs a physical knob was the most reliable way to perform a grab. In other words, it offered the right affordance for this particalar technical system. The stylistic of a brass knob was because I thought that that fitted in with the wooden frame of the blackboard.

I made the 'selection trigger' colour of the text input field red since the participants expressed confusion about if they had 'clicked' the input field or not.

That the non-root nodes are styled as a sort of tree growing from a dirt sphere was due to feedback that it was hard to distinguish between the root and non-root nodes. I also had an intention of keeping the real-world stylistic, even if not a real-world functionality connected to the objects (real-world bushes do not often display text, are backlit or grow floating in the air).

The parent indicator object is styled as a tree, to try to induce an association to an information tree. I also tried to give the indicator an impression of being 'shrunk up' when parents are not expanded, to offer an affordance that something is contracted and can be expanded. To highlight the indicator, in the spirit of nudges, I added the particle system, which I hoped would draw attention to the indicator that it is interactable.

There was positive feedback for the jogger of version 2, so I added more 3D models. The watering can did not move, but the Earth did.

5.6.3   Formative tests of version 3

First participant

Engineer, 26 years, working with optics and software development (the same as in the tests of version 1).

- "It was not obvious that one should poke exactly where it said 'Poke me here'." The participant tried poking all over the panel.

- No trouble with grabbing and moving the blackboard.

- When trying to select the text input field, poked through and due to the panel being placed far back and the trigger area not being where the virtual panel appears, hit the physical computer screen. Had to move the virtual panel in order to be able to click it.

- The base node jumped (due to some misreading by the Meta, I presume) and ended up inside the physical table the computer screen was placed on, which meant that I had to move the panel from Unity so the test could continue.

- Did not noticeably grab the parent sphere, but it triggered nevertheless.

- Tries to fold out parents' parents, which is not possible in this version.

- Searched for jogging and looked at the jogger from a number of perspectives.

- Was impressed by the Earth model, spoke about this being "like sci-fi" and "the kind of thing one wants to see in AR". They also wanted very much to be able to rotate the model themselves.

5.6.4 Conclusions after version 3

The text input functionality is still not optimal. In a way, I am 'stuck' with the Meta mouse interaction model if I do not want to implement a whole other way of specifying the lookup term. As I have discussed above, this was not a priority at this stage of the project, in fact I had originally put that down as a constraint (see section 5.4). I have also discussed that I tried to tweak the parameters of the text input field 'click' triggering (see section 5.4.4), but alas, to no marked avail. The triggering interaction became marginally better, but it was still confusing to users and one had to seemingly poke 'through' the panel in order to reach the triggering point.

The curtailed functionality of not being able to expand parent's parents is not in line with what I want the program to be; in that regard version 1 is more in line with my vision. However, for this version (3) I wanted to focus on evaluating the design of the root node and the new design of the parent nodes. I felt I did not receive enough feedback to properly decide upon keeping the design or not. However, I had received negative feedback about the earlier design, I received no obvious negative feedback for the new design and I also think that the new design is nicer.

The addition of more 3D models was received with markedly positive response.

There are some hiccups that seem to be due to the Meta, either errors in tracking or that one needs to adjust to its interaction model

even more. It is hard to say which is the case. What one can say is that
when users, and I, have used the headset it sometimes triggers grabbing
when it is not intended and sometimes objects 'jump' to unexpected
places.

I could try to make the '*Poke me here [..]*' instruction clearer. How-
ever, as part of my tests I let the users try the Hands tutorial first, with
the ambition to try to teach them how the Meta and its grab interaction
works. This to reduce the '*everything's new, whoa*' effect when the users
try WikUp. In other words, the effect of never or rarely having tried an
AR product or technology before, and that the fact that having that first
experience lessens the possibility that I will get accurate feedback on the
design of my program. To continue, the interaction for selecting the text
input field is not taught to the user. This could partly explain why there
is much confusion about how to perform that task. One improvement
could be to include some sort of tutorial on that specific interaction in
the 'pre-amble' of the user tests. But, I want to reiterate, the original
vision called for a more lightweight and non-intrusive technology. The
choice of the Meta for this project was that it was the best technology
product available, but I would pose the argument that this is a medium
for realisation of the idea and that the idea can be separated from the
realisation. One goal of this thesis is also to explore how to design for
AR, and one conclusion from the discussion above can be simply that
this is probably not the best interaction for the AR medium.

6. Final user test

For the final user test a more summative approach was taken. There were a number of tasks that the users received. These tasks were shaped so that they incorporated the features of this version of the program. The version used here is Version 3 (see section 5.6).

6.1 Structure of the tests

A general description of the test procedure follows:

- The user filled out a pre-survey. This survey can be found in Appendix B. The survey mainly regarded demographics.

- The user read instructions for the tests. These instructions can be found in Appendix B.

- The user went through a tutorial for the Meta 2, where they received an explanation of the Meta's available interactions and got a short training session with the interactions.

- The user used WikUp and was given some tasks to perform in it. These tasks can be found in Appendix B.

- The user filled out a post-survey. The first part of the survey was the SUS (System Usability Scale). The full survey can be found in Appendix B. The non-SUS part of the survey regarded if the user has a need for WikUp, situations they may potentially see themselves using it in and if they believe in the idea separated from the technology.

6.2   Results from the tests

Pre-survey

There were in total n=8 participants. Of them, two (2) were female and
six (6) were male. Five (5) were in the 21-25 years age group, two (2)
were in the 26-30 age group and one (1) in the 31-35 age group. See
Figure 6.1. All but one of the males fully agreed to the statement '*I
am used to using technical products*' while one female and the remaining
male partly agreed, the last female slightly disagreed with the statement.
All participants studied engineering at LTH. Five (5) of the males stud-
ied Information and Communications Engineering Technologies, the last
male studied Mechanical Engineering with Industrial Design and the
females Biomedical Engineering.

Test

In Table 6.1 the time taken per participant and task can be seen. For
all of the participants there was trouble with performing the 'poke'
interaction (to select the text input field, see for example section 5.4.1).
For most of the participants (6 of 8) I had to intervene and press the
`F8` button to re-activate the keyboard (see section 5.4.1). Half (4 of 8)
tried to at least once explore parents by poking the text on the panel
describing what parents a term had. One participant tried to grab the
text input field. For three of the participants I had to help them expand
parents by prompting "*Do you see anything else you can interact with?*".
For one of those I also had to prompt "*Try the green thing*".

Jag är såhär gammal:

8 svar

- 16-20
- 21-25
- 26-30
- 31-35
- 36-40
- 41-45
- 46-50
- 51-55
- 56-60
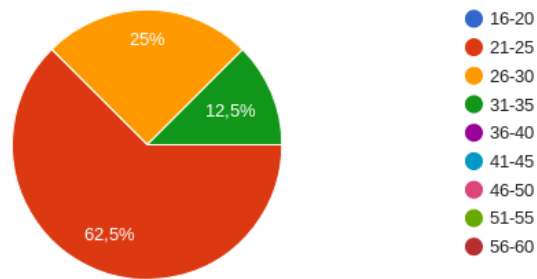
Jag identifierar min könstillhörighet som:
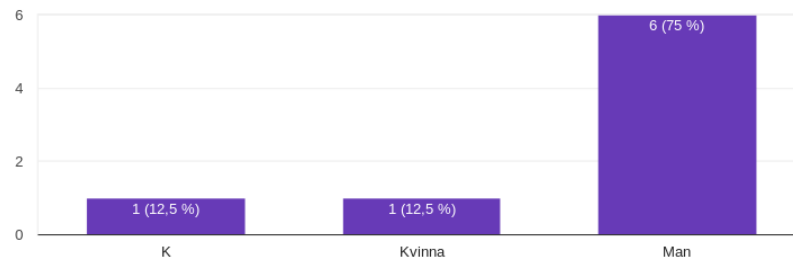
8 svar

Påstående: Jag är van vid att använda tekniska produkter.

8 svar
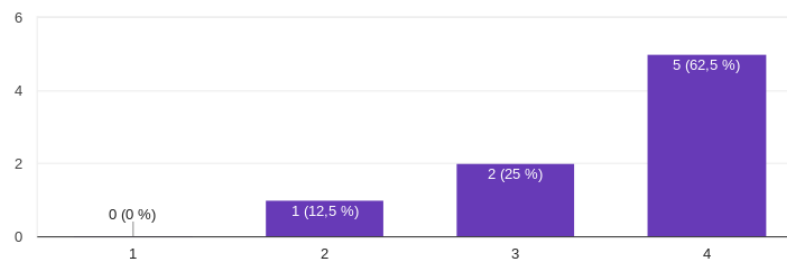
Figure 6.1: Results of the demographics questions in the pre-survey.

Table 6.1: This table shows the time taken to complete each of the tasks for each of the participants.

Participant	Task 1	Task 2	Task 3a	Task 3b	Task 4
1	00:49	-	-	-	-
2	01:22	01:05	00:26	01:03	00:25
3	01:20	01:23	00:10	<-	01:52
4	01:15	00:45	00:31	00:23	00:21
5	01:54	00:49	00:07	00:25	01:00
6	01:02	01:23	00:07	01:05	01:47
7	04:23	00:14	00:11	02:16	01:27
8	00:58	00:35	03:17	00:14	00:20

Post-survey

The SUS scores differed between participants, see Figure 6.2. The calculated average SUS score was **65.625**. This is, according to the US government pages on SUS, slightly 'below average' [72].
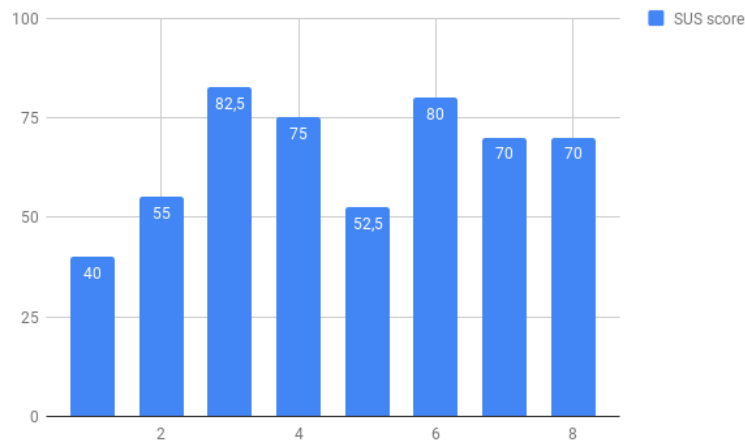
Figure 6.2: A bar diagram showing the calculated SUS scores of each participant.

On the question about which contexts they could see themselves using WikUp in:

- "Fact checking, either being in a lecture or more generally when something is mentioned which seems to be false."

- "For example sitting by a piano and looks for sheet music or similar"

- "Given that I have an AR headset-> When I want to look up terms in a more 'visual' way. It feels comfortable being able to manipulate objects however one wants in the space you are in."

- "In an environment with well-integrated AR where many new concepts can arise which a want to relate to each other or show at the same time, I can see that this could be preferable to a thousand wikipedia tabs."

- "Watching a lesson and needs to know what a word means"

All participants answered 'Yes' to the question regarding if they would be more prone to using WikUp if the technology product had been different (e. g. smaller, not tethered to a computer).

7. Discussion

7.1 Vision of idea compared to current technology

The vision of the idea might have required technology that is not readily available today. Ideally one would have used lightweight AR glasses (more like Google Glass than Meta 2) or contact lenses, and a thought interface. This was also expressed by several participants of the summative user tests, as well as in informal discussions with friends and family during the project. Alas, since those technologies are not well developed or available today, I had to make do with what was, in fact, available.

7.2 Design process considerations

Number of hi-fi prototype iterations

I feel that more iterations of the hi-fi prototype could have been healthy for a number of things. Firstly, it would likely result in a more mature design. Secondly, it would allow for more of the visionary features (see e. g. Figure 1.1, Figure 1.2, Appendix A and section 1.1) to be included in the final design. Thirdly, I quickly found out (which did not come as a particular surprise since this is one of the main points of doing usability tests) that very valuable feedback was coming from the users.

There were several reasons for the number of iterations. The first part of the project, the exploratory phase, allocated its share of the total available time in the project. Learning about Wikidata, RDF and SPARQL, and how to query Wikidata in a good way also took time. So did the lo-fi design, and I also had a period where I both learned how to use the Meta SDK and also had to learn more about Unity and C# in

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order to achieve what I wanted to create.

One thing to keep in mind here is the word 'prototype'. One of my goals was to create a prototype, I worked by doing lo-fi and hi-fi prototypes, and in my vision another format of the technology would be used. This naturally means that limitations will be applied and that many 'darlings' will be inhumed.

Lack of explicitly defined user base

I did not define an explicit user base or create user personas. I had discussions with my supervisor and others about this, and it was I who was averse to the idea. I am aware that defining a target user base (or researching what one could or should be) is usually one of the basic and first things one does for a product. However, for my idea I felt that such a solution could be applicable to a large part of the population. Everybody has to learn in their lives. I felt in part that it would be too restrictive to aim for a more narrow user base.

This approach has a few negative aspects; a more narrowly defined user base than basically 'everyone' (a truth with modifications) would likely result in more natural and specific goals and requirements. E. g. using this program for university students that are in large lecture halls would mean that they cannot use voice control, the interface cannot be too intrusive or cluttered in order to not distract from the lecture but simply augment it, etc. Finding persons to participate in the usability tests would also have been different with an explicit user base.

7.3   Choice of technology

I had a phase where I explored different technologies and products in order to decide which would be the best fit for my attempt at realising my idea. I feel that much of the discussions and rationales for decisions contained in chapter 4 are valid even post project.

Nevertheless, there are some discussion points around the product of my choice, the Meta 2. Something absolutely worthy of mention was the fact that all of the participants in my usability tests had trouble with grasping and performing the poke interaction. As I describe in section 5.4.1 the inclusion of this feature and interaction method was not originally planned and was done on the basis of *'it's better than*

nothing'. In retrospect, the interaction method was problematic. At the same time, with no way of at runtime specifying lookup terms the program would be comparatively poor in features compared to the vision. That makes me feel that its inclusion was net positive, in spite of the obvious shortcomings and issues during the usability tests. One thing that could be done was to include that interaction method in a pre-test tutorial, much in the same way the grab interaction method was taught to the participants in the Hands tutorial.

7.4 Possibility of widespread adoption

In its current status widespread adoption is probably not likely. A realisation on another medium would probably have a better chance. However, there seems to be a consensus right now that AR will not have its largest successes in the regular consumer sphere; rather, its imminent spread will be in industry. WikUp could have use in several different industries. However, in the spirit of democratisation of knowledge it would be nice to offer this solution to the public. But, there are some problems with assuming most people will have access to modern, expensive AR technology: socioeconomic status, not everyone wants the same thing, privacy issues, resource limitations which could compromise creating state-of-the-art technology products, and so on.

8.   Conclusion

8.1   Fulfilment of goals

Here follows an evaluation for each goal:

Explore the possibilities of the original idea   I have explored different technologies and products available to me today. I have learnt more about RDF, SPARQL and Wikidata, which would allow for more complex use cases than used in this thesis. I have storyboarded the idea and also explored different ways of designing features. I have built a working prototype with an existing technology. There are several features in the vision that is not existent in the prototype, but nevertheless, several features do in fact exist and work. I have evaluated some features of the idea and have gotten very useful feedback, both from usability tests and discussions with people around me during the duration of the project.

In conclusion, I believe I have absolutely made progress in regard to this slightly imprecise goal.

Explore how interactions in AR can be designed in order to further usability   I found Metavision's guidelines (see section 4.4.1), which contained some concrete tips for designing for AR. I have evaluated different designs I have made, and found some things to do, and some things to perhaps *not* do.

For this goal, I believe I have made progress. More focus could of course have been allocated towards this goal.

Explore the integration of several MR techniques in order to simulate a more complex product. This goal could probably be

seen as not achieved, at least to the same extent as the two above. At the same time I researched, and tried, different ways to integrate different products. The LMC with a WMR HMD or the Hololens, and different ways of achieving such an integration. I also 3D printed a mount for such an integration. I chose to follow a path that led me away from this goal by using the Meta 2, and even though that decision resulted in a few issues I still believe I made an informed choice that gave me as good opportunities I could get today of realising my idea.

Produce a light-weight, non-intrusive, 'minimum viable product' prototype with good usability. In retrospect, this was a fairly richly specified goal. Let me break it down into its individual parts:

- **Light-weight**: in a literal sense, the Meta was a heavy headset. In a conceptual or perceptual sense, one can argue for both yes and no. Both version 2 and 3 of the WikUp prototypes had a limited feature set and did not have a cluttered interface. Version 1 had more nodes, and since the automatic placement at spawn of parent nodes did not work correctly in this version, as well as the fold in-fold out functionality of the parents also being buggy, the interface could be considered a bit cluttered. At the same time, the participants did not seem particularly overwhelmed. I would say that this goal can be considered achieved.

- **Non-intrusive**: this, I feel, cannot honestly be considered achieved considering the headset being used; several users voiced complaints about it being heavy or worsening already existing headaches. The fact that the headset has to be tethered to a computer as well as a power outlet and that it has a not-so secretive shape further strengthens this conclusion. As for the virtual objects, they were not as intrusive (part of the justifications for the *light-weight* goal above can be imported here, though).

- **MVP**: I actively made conscious limitations for the feature set, and I wanted to focus on two basic functionalities: performing a lookup on a term of choice, and exploring hierarchical relations emanating from that term. Those functionalities could be achieved with these prototypes, and for especially the lookup functionality I received positive feedback from users. Thus, I would consider this goal achieved.

- **Good usability**: this one not as easily decided upon. There were obvious issues even with the last prototype, such as 100% of users having trouble grasping the poke functionality. With the risk of coming off as deflecting responsibility, much of what the users gave negative feedback about came from the Meta and its interaction models. This made it a tad hard to properly evaluate my design and the usability of my prototype. At the same time the average SUS score was 65.625, which as stated above is slightly below average but not in the range of obviously unusable. So, was this goal achieved? Yes, in part, but there is absolutely room for improvement.

8.2 Take-aways for designing in AR

Utilise affordances smartly: design so that affordances match how the technical devices works best (as e. g. with the knob in section 5.6.2).

Mimic real-world objects responsibly: utilising users' previous knowledge can be powerful, but one can also be limited to the affordances and functionalities of the real-world object.

Think about the most fitting paradigm: carrying over interaction models and functionalities from the desktop paradigm to AR can sometimes be fitting and sometimes useful, since the users carry that mental model. However, it may also be confusing. That paradigm is a learned model, and AR with a HMD is a very different environment.

Minimise the novelty factor when evaluating: since AR with HMD's are not widespread, many people have not had the chance to try it. This makes evaluating the design of a program harder, since there is the effect of the whole experience being new. One way to mitigate this is to let participants in a usability test do one or more tutorials for the HMD/medium, in an attempt to separate the 'new AR experience' and the program's design.

8.3   Concluding

I enjoyed working on this project. I learnt more about augmented reality, Unity, Python, C#, web technologies, about Wikidata, RDF and SPARQL, and all of these (with perhaps the exception of C#, but I certainly do not regret knowing more about that language) were things I was interested in learning more about. I also learnt more about design, both theoretical and practical sides of it. Carrying through with a fairly large project of my own was also challenging but satisfying. I of course have a critical perspective of the idea and the realisation of it I produced in this project, but at the same time I am satisfied with the project and its results.

9. References

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A.   Appendix: Storyboards

Figure A.1: The user folds out a node by touching an arrow on the parent node.
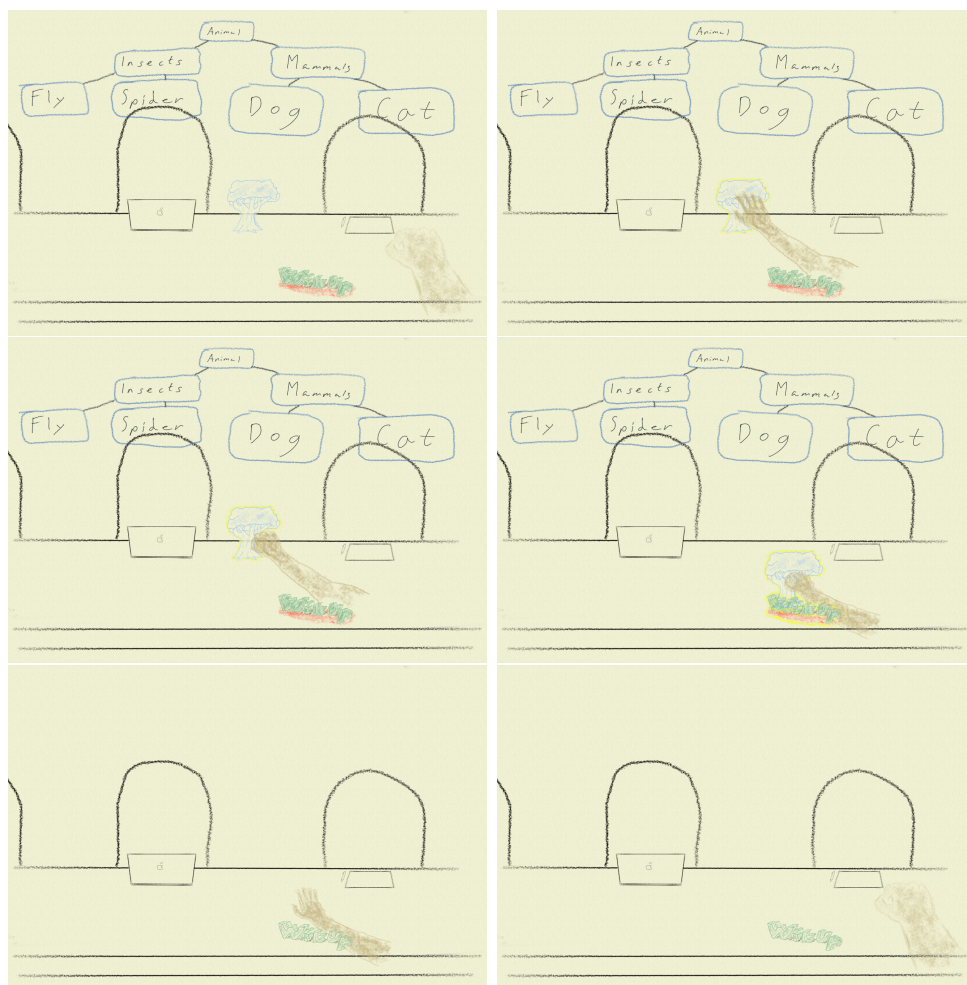
Figure A.2: The user exits the lookup by grabbing the tree anchor and 'putting it back' into the WikUp logo.

B. Appendix: User tests material

Here, I include the user test instructions I used in the user tests.

B.1   Formative user tests

Välkommen!

Jag jobbar på ett program som ska hjälpa en att lära sig ny information och ta sig in i ämnesområden som är nya för en. Tanken är att detta ska göras genom att göra en sökning på en term eller bokstavsförkortning och få upp essentiell information för att få en snabb uppfattning om vad termen/förkortningen innebär.

Ett möjligt användnings-scenario är att sitta på ett möte på ett nytt jobb, och när någon nämner ett ord en inte vet vad det är eller innebär, kan en använda programmet för att snabbt få ett hum, och då kunna förstå och vara med i diskussionen.

Tanken är också att programmet skulle göra sig bäst med AR-kontaktlinser eller dylikt, men eftersom den tekniken inte finns tillgänglig idag använder jag detta headset :-)

Instruktioner

Först ska du sätta på dig headsetet, sedan få göra en kort tutorial för att lära dig hur en använder det, och sist ska du få testa en version av mitt program.

Hur headsetet bör sitta

Vid pannan ska det sitta precis ovanför ögonbrynen.

Det finns två sätt att justera headsetet:

Vad:	Används för att:
Skruv på baksidan	ändra omkretsen på headsetet
Tygremsa på toppen av huvudet, använder kardborreband	styra hur högt upp på huvudet headsetet sitter

När det sitter bra gör det inte ont någonstans eller halkar omkring, och virtuella objekt och text visas utan att vara oskarpa. Det är okej att när som helst ändra hur headsetet sitter.

Hands tutorial

Följ bara instruktionerna som kommer upp på skärmen.

Starta upp programmet

Headsetet vill göra några saker först för att orientera sig. Det kan upp till två gånger komma upp detta:
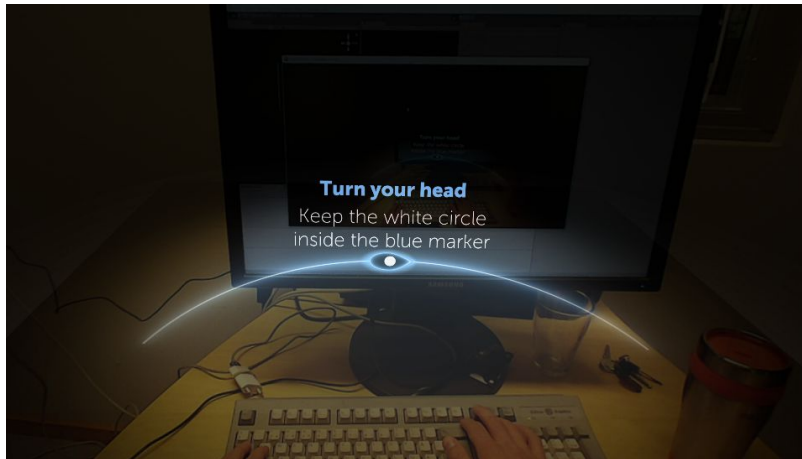
Följ bara instruktionerna, när du rör på huvudet flyttas den vita bollen. Försök röra huvudet så att den vita bollen stannar inom den blå cirkeln. Cirkeln kommer att flyttas till höger och tillbaka.

När headsetet känner sig bekvämt med omgivningen, visar det detta:
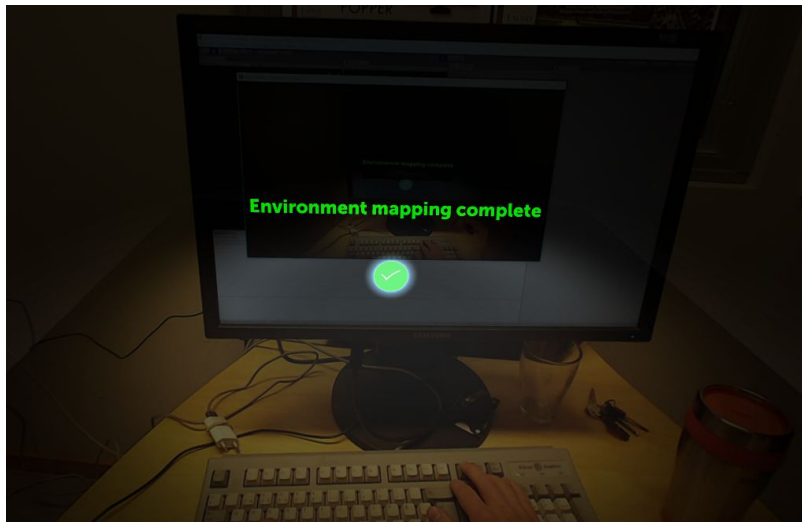
Då är det klart, och du kan börja med instruktionerna för mitt program, vilka följer nedan.

(Mitt program kommer eventuellt visas upp mellan dessa saker som ses i bilderna ovan, men bara låt det vara och följ instruktionerna, och vänta tills den gröna texten dykt upp.)

Instruktioner att utföra:

Under hela tiden, **prata högt** om vad du ser och vad du tänker om det du ser!

Notera att du också kommer använda dig av det fysiska tangentbordet.

1. Flytta den svarta tavlan närmare dig.
2. Gör en sökning på 'dog'.
3. Gör en ny sökning på 'jogging'.

B.2   Summative user tests

Frågor innan test av WikUp

1. **Jag är såhär gammal:**
   Markera endast en oval.

   ⬭ 16-20

   ⬭ 21-25

   ⬭ 26-30

   ⬭ 31-35

   ⬭ 36-40

   ⬭ 41-45

   ⬭ 46-50

   ⬭ 51-55

   ⬭ 56-60

   ⬭ Övrigt: _____

2. **Jag identifierar min könstillhörighet som:**

   _____

3. **Påstående: Jag är van vid att använda tekniska produkter.**
   Markera endast en oval.

	1	2	3	4	
Stämmer inte alls	⬭	⬭	⬭	⬭	Stämmer helt och hållet

4. **Min sysselsättning är:**
   (Om student, skriv gärna också vilken inriktning.)

   _____

Välkommen!

Jag jobbar på ett program som jag kallar för WikUp. Ambitionen är att det ska hjälpa en att lära sig ny information och ta sig in i ämnesområden som är nya för en. Detta ska göras genom att göra en sökning på en term eller bokstavsförkortning och få upp essentiell information för att få en snabb uppfattning om vad termen/förkortningen innebär.

Ett möjligt användnings-scenario är att sitta på ett möte på ett nytt jobb, och när någon nämner ett ord en inte vet vad det är eller innebär kan en använda WikUp för att snabbt få ett hum, och då kunna förstå och vara med i diskussionen. Det kan också vara att sitta på en föreläsning i en kurs och inte minnas vad en term som togs upp förra veckan innebar, och då använda WikUp för att fräscha upp minnet. Det kan också vara när en ska använda en (för en själv) ny sorts produkt, ex en borrmaskin, sminkprodukt eller cykelpump, och i instruktionerna stöta på en term en inte känner till.

Instruktioner

Först ska du sätta på dig headsetet, sedan få göra en kort tutorial för att lära dig hur en använder det, och sist ska du få testa WikUp.

Hur headsetet bör sitta

På pannan ska det sitta precis ovanför ögonbrynen.

Det finns två sätt att justera headsetet:

Vad:	Används för att:
Skruv på baksidan	ändra omkretsen på headsetet
Tygremsa på toppen av huvudet, använder kardborreband	styra hur högt upp på huvudet headsetet sitter

När det sitter bra gör det inte ont någonstans eller halkar omkring, och virtuella objekt och text visas utan att vara oskarpa. Det är okej att när som helst ändra hur headsetet sitter.

Hands tutorial

Följ instruktionerna som kommer upp på skärmen. När du ska ta tag i saker, håll händerna framför headsetet så att headsetet 'ser' dem. När det går att ta tag i saker syns en blå cirkel på handen.

Headsetet vill göra några saker först för att orientera sig. Det kan upp till två gånger komma upp detta:
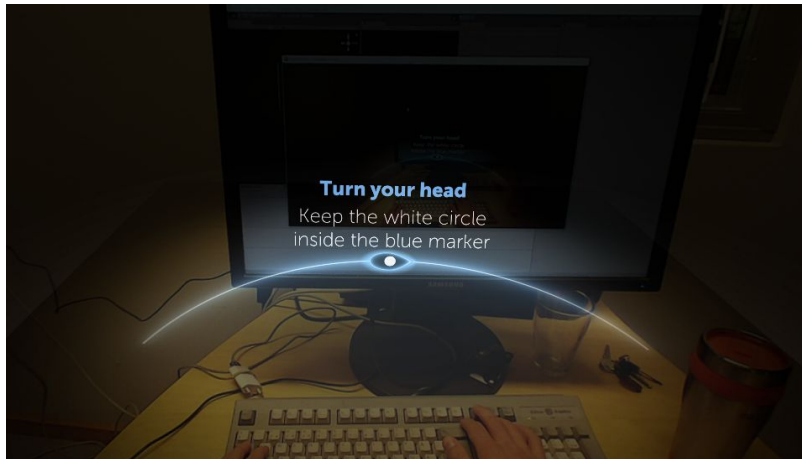
Följ bara instruktionerna, när du rör på huvudet flyttas den vita bollen. Försök röra huvudet så att den vita bollen stannar inom den blå cirkeln. Cirkeln kommer att flyttas till höger och tillbaka.

När headsetet känner sig bekvämt med omgivningen, visar det detta:
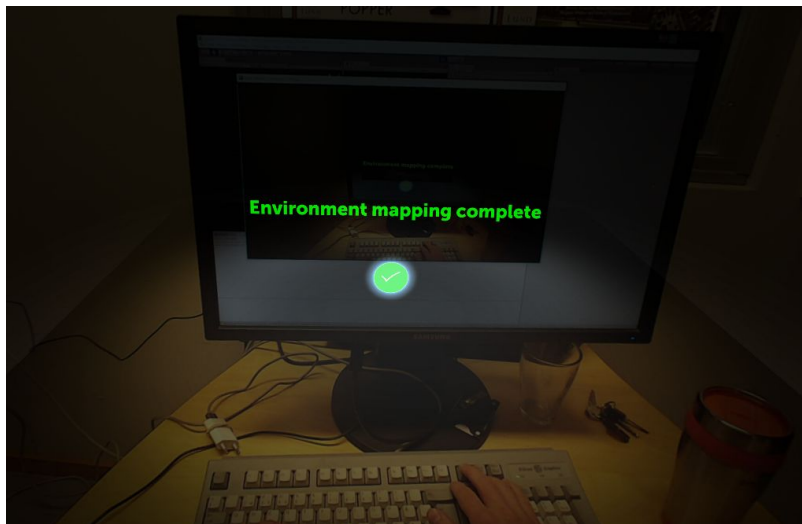
Då är det klart, och du kan börja med Hands tutorial.

Dags för WikUp!

Samma orientering som innan Hands tutorial görs troligtvis här också. Mitt program kommer eventuellt visas upp mellan vyerna som ses i bilderna ovan, men bara låt det vara och följ instruktionerna, och vänta tills den gröna texten dykt upp. Då är orienteringen klar och det är dags att börja använda WikUp.

- *Notera att du kommer använda dig av det fysiska tangentbordet.*
- *Notera också att programmet är på engelska, så skriv dina sökningar på engelska.*
- *Pausa gärna lite efter varje utförd instruktion innan du börjar på nästa*

Instruktioner att utföra:

1. Du sitter på en föreläsning och föreläsaren nämner förkortningen *EEG*. Du minns inte vad det står för. Använd Wikup för att ta reda på det.
2. Du läser till personlig tränare. Vid tentaplugg blir du ombedd att ge den exakta definitionen av *jogging*. Använd WikUp för att hitta definitionen.
3.
    a. Du är på en restaurang för att äta lunch. I menyn ser du *BLT* och undrar vad det är för något. Ta reda på vad det är för något.
    b. Ditt lunchsällskap undrar över hur den mat-typen ser ut. Från ditt sökresultat kan du hitta svaret.
4. Du umgås med din åttaåriga släkting. Hen har nyss lärt sig om att det finns fler planeter i rymden än våra. Hen frågar dig hur många andra planeter som finns mellan oss och Solen. (Tips: Jorden heter *Earth* på engelska.)

Frågor efter test av WikUp

Enkät på engelska

1. **I think that I would like to use WikUp frequently**
   Markera endast en oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

2. **I found WikUp unnecessarily complex**
   Markera endast en oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

3. **I thought WikUp was easy to use**
   Markera endast en oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

4. **I think that I would need the support of a technical person to be able to use WikUp**
   Markera endast en oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

5. **I found the various functions in WikUp were well integrated**
   Markera endast en oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

6. **I thought there was too much inconsistency in WikUp**
   Markera endast en oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

7. **I would imagine that most people would learn to use WikUp very quickly**
   Markera endast en oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

8. **I found WikUp very cumbersome to use**
   Markera endast en oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

9. **I felt very confident using WikUp**
   Markera endast en oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

10. **I needed to learn a lot of things before I could get going with WikUp**
    Markera endast en oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

Frågor på svenska

11. **Jag skulle ha användning av WikUp när jag ska lära mig nya saker**
    Markera endast en oval.

	1	2	3	4	
Stämmer inte alls	◯	◯	◯	◯	Stämmer helt

12. **I vilken sorts sammanhang hade du kunnat tänka dig att använda WikUp?**

_____

_____

_____

_____

_____

13. **Hade du varit mer benägen att använda WikUp ifall tekniken hade sett annorlunda ut? (Ex ifall headsetet var mindre, inte kopplat till dator etc)**
Markera endast en oval.

⬭ Ja

⬭ Nej

⬭ Övrigt: _____

Tack så mycket!

C.   Appendix: Data from summative user tests

C.1   Data from pre-survey

The results can be seen in table C.1. The four questions were:

1. Jag är såhär gammal (*I am this old*)

2. Jag identifierar min könstillhörighet som (*I identify my gender as*)

3. Påstående: Jag är van vid att använda tekniska produkter. (*Statement: I am used to using technical products.*)

4. Min sysselsättning är (*My occupation is*)

Table C.1: The answers to the pre-survey.

Participant	Q1	Q2	Q3	Q4
1	26-30	Kvinna	2	Ingenjörsstudent BME
2	26-30	Man	4	Student Infocom
3	21-25	Man	4	Student, informations och kommunikationsteknik. Även Service underhållare
4	21-25	Man	4	Student: Infocom LTH
5	21-25	Man	4	Student, Teknisk Design
6	21-25	Man	4	Student, infocom
7	21-25	K	3	Student BME
8	31-35	Man	3	Student (IT)

C.2 Data from tests

- if = text input field
- using quotes (") signifies something the participant said or searched for, apostrophes (') signifies something I said.

C.2.1 Participant 1

Not: har gjort formativa tester också
- feedback på instruktioner: "Det du kommer att prova nu är någonting jag kallar för WikUp"

Task 1

- klarade, lite problem med att trycka på inputfield
- 00:49

Task 2

- klarade
- lite förvirring med if
- panelen åkte iväg utan anledning, går inte att få tag i

    - råkade fälla ut parents vid retrieval

Task 3a

- mycket svårt med if
- behövde trycka F8

Task 3b

- gick bra, men ville trycka på parents på panelen
- "lite rörigt med träd, även om snyggt"

    - "alt svart bakgrund bakom texten"

Task 4

- if-problem
- gick bra ändå

not

- Det var extra mycket problem med if, kan ha blivit för koppla ur Meta och sedan söva datorn. Kanske köra 'fräscht' inför nästa test.

tips

- jämför med annan AR-grej, undvika att det blir AR-grejen man utvärderar
- fråga i innan-enkäten om erfarenhet med AR

C.2.2   Participant 2

Task 1

- poke interaction not obvious
- "marijuana plant?"
- 01:22

Task 2

- poke problems
- förvirrande med två cirklar
- råkade trigga sök igen
- svårt med poke
- sökte på definition of jogging
- 01:05

Task 3a

- inte tydligt att a inte ingick i 3
- 00:26

Task 3b

- "ser inget direkt"
- ingen joggande person
- 'ser du något som verkar gå att interagera med?'
- "marijuana" igen
- 01:03

Task 4

- gick bra
- 00:25

notes

- "gillar att den highlightar på objekten"
- råkade triggas på grab vid *fel* tillfällen, så vid två tillfällen (efter test) hamnade panelen under skrivbordet.

tips

C.2.3   Participant 3

Task 1

- 'tryck F8'
- problem med grab
- fick starta om programmet, input slutade funka
- problem med grab
- lekte med wikup-logga
- 00:20 (i andra run, först i 1+ minut)

Task 2

- svårt att fokusera input field

- upptäckte andra cirkel, på panelen

- "kan man klicka på parents?"

- peta upp parentes

  – tyckte det var coolt

- 01:23

Task 3a

- petade upp parents även här
- 00:10

Task 3b

- avklarad i task 3a

Task 4

- söker på "planets between .."
- la till "the"
- "ow many planets.."
- "solarsystem"
- "3"
- 'testa att läsa ledningen'
- sökte då på earth
- 01:52

notes

- "fett att du får med 3D-modellering"
- "kan inte flytta jorden?"
- petar på jorden
- problem med att grabba

tips

- vid ifyllande av efter-enkät: "om du vill ha förklaring på varför svar, pga det är just detta headset, om det hade varit typ google glass hade jag varit mer benägen"
- "förväntade mig mer information i ansiktet, trevligt med lite mer träd etc."

C.2.4   Participant 4

Task 1

- pokade, men det tog inte
- gick först trigger, sen släppte
- försöker hålla inne trigger och skriva
- F8
- håller kvar
- 01:15

Task 2

- håller kvar poke medan skriver
- gick bra
- 00:45

Task 3a

- upptäckte att inte behövde hålla
- råkade söktrigga ädå
- svårt med poke
- 00:31

Task 3b

- flyttar upp panelen
- poke gick bra
- söker på sandwich
- "tror jag hade panelen för nära mig"
- 00:23

Task 4

- poke gick bra
- söker på Earth
- 00:21

notes

- stör highlighting av text?
- söker på "solar system"

tips

C.2.5   Participant 5

Task 1

- lätt att grabba
- svårt med poke
- vill grabba för poke
- pokear inte tillräckligt långt in
- fick säga 'testa att tryck mer genom fältet'
- fattade cirkelns funktion
- 01:54

Task 2

- poke bra
- bytte fönster med fysiska musen
- F8 två gånger
- 00:49

Task 3a

- snabb
- 00:07

Task 3b

- "hur den ser ut?"
- petar på text-parents
- petar på text
- lyckades
- försöker peta på parent-trädet
- fällde in och ut parent
- upptäckte markör på parent, tyckte de borde fungera likadant
- 00:25

Task 4

- "planets in the", sökte inte
- "solar system"
- försöker peta på planetary system
- söker på "planetary system"
- "vill inte följa ledning men gör det nu"
- earth
- +40
- 01:00

notes

- "lite för tungt för att det ska sitta bra"
- "huvudvärksmaskin"

tips

C.2.6   Participant 6

Task 1

- "var är tangentbordet?"
- prompt om fysiskt tangentbord
- poke-problem
- F8
- 01:02

Task 2

- poke rätt bra
- råkade trigga sök
- min ahk
- avmarkerade då unity
- försöker markera texten med click-and-drag
- F8
- 01:23

Task 3a

- gick
- 00:07

Task 3b

- såg trädet
- kollar sig runt
- "blev ingen macka"
- prompt 'ser du något att interagera med?'
- släpper inte grab
- pokade upp parent
- försöker pokea parent
- 01:05

Task 4

- testpokear
- "how many planets is there between the earth.."
- markerar all text innan ändring
- funderar
- "planets between the earth and the sun"
- tar ner parent

- "planets earth sun"
- prompt 'har du läst ledningen?'
- "earth"
- 01:47

notes

- ville svara utifrån idén och inte meta:t på enkät
- "meta krånglig att använda"

tips

C.2.7 Participant 7

Task 1

- testar peta på panel

- oklart med poken

- föröker skriva direkt

- föröker peta på mitten av panelen

- prompt 'testa att trycka där det står *here*'

- selectade inte

- prompt 'tryck längre fram, genom'

- då

- prompt 'peta igen'

- slutade focusa vid skrivande

- F8

- "hel"

- disamb

- hade missat min instruktion att börja med tasks

- 04:10

- sen gick det bra

- 00:13

Task 2

- gick bra
- 00:14

Task 3a

- 00:11

Task 3b

- tittar in på parents-texten
- tittar på parent-tree, tittar bort igen.
- igen titta, bort
- titta runt
- tittar nära på panelen
- läser task
- prompt 'ser du fler saker att interagera med?'
- flyttar panel
- petar nästan på parent-tree
- flyttar panel
- når inte upp till p-tree
- prompt 'grön sak'
- 02:16

Task 4

- flyttar panel
- av-focus på if
- fällde in parent
- petar på if men inte tillräckligt långt fram
- prompt 'längre fram'
- tittar på instruktion
- earth
- 01:27

notes

"går det att luta panelen?"

tips

C.2.8   Participant 8

Task 1

- pokear försiktigt
- försöker grabba tf
- lyckades pokea
- F8
- 00:58

Task 2

- försöker pokea, panel nog för nära
- upptäckte att det gick att flytta
- lite pokeproblem men löste sig snabbt

- 00:35
- flyttar runt panelen runt sig
- "trodde en skulle behöva memorera och svara på frågor efter"

Task 3a

- pokear helt genom panel
- flyttar närmare
- lyckas inte focusa
- försöker trycka med hela handen
- råkade trigga parents
- tror att headset är dåligt inställt och därför hen inte såg ickutfällda parents
- försöker grabba parents-bollar på träd
- försöker grabba träd
- inputcirkel låser sig helt
- 03:17

Task 3b

- inputcirkel fortf halvbra
- 00:14

Task 4

- "earth"
- 00:20
- försöker peta på inner planet

notes

- testar vidare:

- "car"

- "human"

- verkar ha fattat parent-utfällning

- "sweden"

- enkät: frågar om värld en ska svara på sus utifrån, ifall folk normalt har headsets på sig etc. visste inte exakt vad jag skulle svara, så sa mest "tänk inte"

tips

C.3   Results from post-survey

The results of question 11 can be seen in table C.2, the results of question 12 in the list below. All participants answered 'Yes' to the question

'Hade du varit mer benägen att använda WikUp ifall tekniken hade sett annorlunda ut? (Ex ifall headsetet var mindre, inte kopplat till dator etc)' *(Would you have been more inclined to use WikUp is the technology had been different? (E. g. if the headset had been smaller, not tethered to a computer etc)).*

Table C.2: Answers to question 11 of the post-survey.

Participant	Jag skulle ha användning av WikUp när jag ska lära mig nya saker
1	3
2	4
3	4
4	3
5	2
6	4
7	2
8	4

Answers to question 13 of the post-survey

- Fact checking, vare sig det är vid föreläsning eller bara rent allmänt när något nämns som verkar falskt.

- T.ex, sitter vid ett piano och kollar upp noter eller liknande

- Givet att jag har ett AR-headset-> När jag vill söka upp termer på ett mer "visuellt" sätt. Det känns bekvämt att kunna manipulera objekten hur man vill i rummet man befinner sig i.

- I en miljö med väl integrerad AR där det kan komma många nya koncept som jag vill relatera till varandra eller visa samtidigt, så ser jag att detta skulle kunna vara att föredra över tusen wikipedia flikar.

- Kollar på lektion och behöver veta vad något ord betyder

- När jag vill slå opp saker och se illustrationer samtidigt

- När jag sitter på en föreläsning