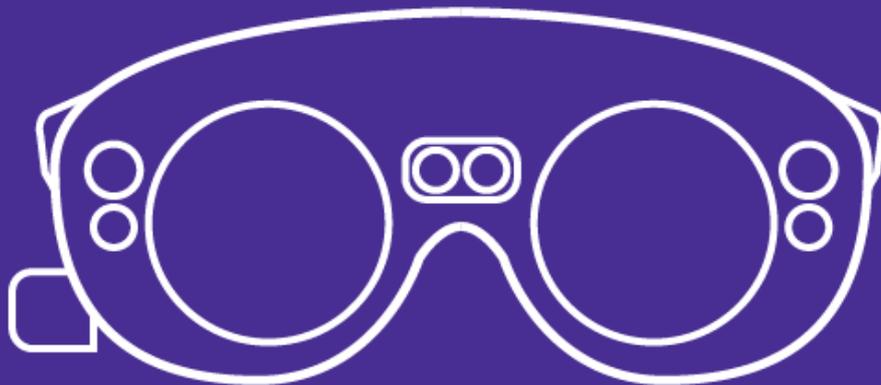


Literature Research

What are UX design guidelines for comparable devices, and how to apply these to AR for wearables?



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Introduction

To validate UX design guidelines for AR wearables, a good understanding of what UX design guidelines are, and how they are used on other, more used, products was needed. These products include: Mobile AR, VR, Screens (desktop and mobile), real-life objects. It is also needed to look at who these guidelines are made for, and how to test them.

What are UX design guidelines?

UX design helps users accomplish goals. It is not focused only on creating products that are usable, it also covers the other aspects of the user experience, such as: pleasure, efficiency, mood and fun. (Interaction Design Foundation)

Design guidelines are sets of recommendations towards good practice in design. They are intended to provide clear instructions to designers and developers on how to adopt specific principles, such as intuitiveness, learnability, efficiency, and consistency. Instead of dictating conventions, design guidelines provide helpful advice on how to achieve a design principle that can be platform-specific or cross-platform.

Design guidelines are needed for a consistent experience throughout a product. (Minhas, 2018) These guidelines are usually defined at a company level and are useful for designers, testers, and developers alike. Minhas states that guidelines are needed for the following reasons:

- They enforce consistent experience throughout your products.
- In addition to specs of UI components, guidelines also describe best practices. It makes easier for a reader to decide about the right choice.
- They make learning easier. New members are trained about standards and behaviours with a little effort.
- Designers don't have to create specs each time they design a feature.
- Developers don't have to wait for specs, and they can refer to guidelines and build interfaces.
- It is convenient to update guidelines based on new standards and trends and update your designs accordingly.

At the heart of every design, there is a function something is expected to perform. (Wax, 2008) The goal of the product must be clear when designing a product. Users must be included in the designer's considerations.

To get structured results, every product (Real life objects, screens, mobile AR, VR) will be examined by looking at the following UX design principles:

- Accessibility
 - How to make the application useful for as many people as possible
 - User fatigue
 - How is it made clear what the application is for?
- Hierarchy
 - How is the hierarchy of the applications on the product done? How are the most important functions visualized.
 - How can a user navigate easily through the product?
- Confirmation
 - How is a confirmation action asked?
 - How is feedback given
- Consistency
 - What makes the experience of product X consistent?
 - How to make input consistent?
- User control
 - How to reset, go back?
 - How is the user expected to control the application?
 - What are other points of control?

These principles were chosen because they are the most common, and because most other principles can be traced back to one of those 5 (Grass, 2018) & (Korkishko, 2019). Most other UX design principles were an addition to one of those (Memon, 2019).

Who are these guidelines for?

To understand why these guidelines are needed, it is first needed to understand for who these UX guidelines are for. To get a better understanding of the stakeholders, I made a model which shows the 3 pillars for a good product. I made this model with the knowledge gained by working in a developer team myself and thinking about how to optimize the quality of the product. With the team I worked with, a working prototype could be made and justified, but with the help of other specialists, the product could be even improved better. In the team, there was one UX designer, two developers and two 3d designers. The head of labs, Bas, could be seen as the consultant/generalist. The pillars in the model are “Consumers, Conceptual, and Technical.” Every pillar has its own specialists and some of those specialists do a combination of two pillars.

The model was discussed with the stakeholders, and it was concluded the model could be used to define what was more important, if there were not enough resources or time to meet the requirements of every pillar.

The UX guidelines for AR wearables would be usable for every aspect within the model, because it important to know what is required to build a good product.



UX guidelines on other products

What are UX design guidelines for objects?

To answer this question, the book “The design of everyday things” (1988) by Don Norman, was consulted. This book explains the communication between object and user, and how to make these as pleasurable as possible.

Affordances are the relationship between the properties of objects and the capabilities of an agent to determine how these objects should be used. The presence of an affordance is determined by the qualities of the objects and abilities of the agent that is interacting. For designers, the visibility of affordances is critical. They provide strong clues for how should be interacted with objects.

Signifiers communicate where the action should take place. When people use objects, they search for clues and signs on how to use the object. These signs are vital for the use of an object and should be provided by a designer. A well-designed object needs communication of the purpose, structure and operation of it.

Mapping means the relationship between the elements of two sets of things. Mapping is important in the design of controls and displays. The relationship between controls and its results are best learned when there is understandable mapping between the controls, actions, and results. A device is easily usable when the set of possible actions is visible. Good design takes care, planning, thought, and an understanding how people behave.

Feedback is the communication of the result of an action. This feedback must be immediate. If the feedback takes too long, the user could be distracted or lose interest. Feedback must also be informative. Users must know the results of their actions. A poor design in feedback can have annoying effects on a user. Feedback must be given in the right amount. Too little feedback, and a user does not know the effects. Too much feedback can be dangerous, because the user can ignore the feedback which can result in valuable feedback being missed. Feedback is essential, but it must be done correctly.

To conclude, the design of everyday things could be of great use when designing an AR wearable application. Because of a different feedback than users are used to on screens, other solutions must be thought of when users must navigate themselves through an application.

Accessibility

The accessibility of an item is defined by the affordance and signifiers of the affordance. The accessibility of an object can be measured by its size, texture, shape, added text, etc.

The user fatigue when interacting with items also depends on the above. If the item is heavy, but is small and has a good grip, it can be easier to lift than an item that is lighter, but slippery and very large. The user is given instant feedback of the accessibility by trying out the object.

Hierarchy

The hierarchy of an everyday object is straightforward most of the time. The most important thing of an object is to do the thing it was made to do. In case of a screwdriver, it is important that it can screw screws. Added values could be a magnetic tip for easier use, but it could still work without this.

Confirmation

The most important thing when looking at the confirmation of an everyday item, is that the feedback is given instantly. When looking at the feedback section of Don Normans book, if the feedback takes too long, a user will lose interest in the product. In case of the screwdriver, the confirmation is given instantly by the screw driving into the wall.

Everyday objects most of the time don't ask for confirmation, because their goal should be self-explanatory. When trash gets thrown away, the trash bin will not ask for the user's confirmation to accept the trash.

Consistency

Consistency in real life objects is made possible by giving a visual recognition of what the object is used for, what the affordance is. A drinking cup for instance, always has a big hollow container to put liquid in. If it wouldn't have this, the object would not be defined as a drinking cup. It would have a different affordance.

User Control

The user control of everyday objects is mostly done by the movement of the person using it. If a user wants to move an object, it can just be grabbed and moved (if it is light enough).

If the user fails to interact the right way with the object, there is no real fail prevention. For instance, when the cup filled with tea falls, there is no way to go back to the moment this has not happened yet.

How can these be used in AR for wearables?

When looking at AR for wearables, a couple of things can be useful. The affordance of a virtual 3d object must be made clear, so the user knows what he can do with it. For instance, when the user wants to draw inside an AR wearable application, it is nice when the object that affords to draw is shaped like a pencil. And when you want to erase your drawing, change the shape of the tool to an eraser.

The use of tools inside AR wearables that are shaped like real life tools will help users with climatizing with this new way of interaction.



What are UX design guidelines for desktop?

Accessibility

Different users need help in achieving their full potential in different ways. What is enabling to some users might harm versatility, directness, and control for others. Well-designed software must balance these characteristics appropriately. For example, a desktop publishing system designed for non-professionals might use wizards to walk users through complex tasks. Such wizards enable the target users to perform tasks that they otherwise wouldn't be able to perform. By contrast, a desktop publishing system for professionals might focus on directness, efficiency, and complete control. For users of such an application, wizards may be limiting and frustrating. (Microsoft, 2018)

In order to provide the best experience possible for your site's visitors, take advantage of the fact that you already know what types of web experiences they're familiar with. You can use this information to make your site easier for visitors to navigate. (Devaney, 2016)

Hierarchy

Organize visual elements from top-to-bottom and left-to-right. This is the direction that people from western locales tend to read an interface, so that the items at the top-left will be encountered first. This ordering gives interfaces a hierarchy: those components that are viewed first are perceived to have priority over those that come after them. For this reason, dominant controls should be placed above and to the left of the controls and content that they affect. Header bars are a key design pattern in this respect. (Gnome, 2014)

Confirmation

Confirmation should be done with a pop-up or alert when the user does an action that cannot be reversed.

Consistency

To make an application consistent, spacing should be used in the same amount throughout.

To obtain simplicity, focus on what is likely; reduce, hide, or remove what is unlikely; and eliminate what is impossible. (Microsoft, 2018)

User control

On a desktop or laptop, the user has 2 specific tools to control the product with, a mouse (touchpad) and keyboard. These tools are specifically made to optimize the use of this product and with it the user can perform tasks very accurately.

When using a controller as tool, the buttons it has should be mapped in a logical and consistent way.

How can these be used in AR for wearables?

Because desktops and laptops have been around for a long time, people do know the guidelines of these devices thoroughly. The use of a qwerty-keyboard has made it easy to type large amounts of text.

For an AR wearable, it is important to not reinvent the wheel and create new standards. Instead use some of the principles set by these "old-school" devices. If users are learning a whole new way of experiencing information, like in AR, it is good to have experiences inside this experience that they are already familiar with.

What are UX design guidelines for smartphones?

Accessibility

Users like it when an app meets their expectations. Use navigation patterns that are familiar to the users, so navigating does not require any explanation.

Every word in your app is part of a conversation with your users. Make this conversation comfortable for them by speaking the same language as your users. Use familiar, understandable words and phrases if you want your app to appeal to everyone.

Hierarchy

For mobile applications it is really important to focus on refining the experience around your core objectives. (Babich, 2018) Because there is limited space to work on, these objectives must be really clear. Know what the core purpose of your app is — analyse which features of your app are used the most and put the most effort into making that experience intuitive.

Prioritize one primary action per screen. Try to design each screen for one thing and one thing only, with no more than one call-to-action. This makes it both easier to learn and easier to use. A few clear screens are preferable to a single cluttered screen. (Babich, 2018)

Confirmation

Based on the type of UI element or current state of the app, designers can use different forms of feedback. For example, interactive elements can be highlighted briefly when tapped, progress indicators can be used to communicate the status of long-running operations, and animated effects can help clarify the results of operations.

Confirmation should be done with a pop-up or alert when the user does an action that cannot be reversed.

Consistency

Navigation controls should always be visible, or at a same location. Never move navigation controls to different locations, or a user could get lost inside the application.

Typefaces, buttons and labels need to be consistent across the app. Interactive elements should work similarly in all parts of your app. Design should be consistent across multiple products. This way, the user can apply prior knowledge when using another product.

User control

Because the mobile phone is controlled by touch, the interactable objects should be big enough and not too close to each other. This will minimize mistakes that could be made by a user. It should be clear what happens when the user presses the built-in back-button of the mobile phone. (Abu, 2017)

It's absolutely normal to use gestures as a supporting mechanism for existing navigation (e.g. navigation shortcuts), but it's better to avoid using gestures as a primary method of interaction with your app (e.g. as a replacement for main navigation). Unless your app is a game, people rarely appreciate being forced to learn different ways to do basic things.

How can these be used in AR for wearables?

Because the user is confronted with a new way of interaction, it is nice to have familiar understandable words or interactions. The built-in gestures of the Magic Leap can be used, but in very small quantities. Users don't like to get forced to learn new gestures for important interactions.

The limited space to work with on a mobile phone can be conveyed into AR wearables. Because of the small FOV of AR wearables, menus should be small enough to fit entirely inside that FOV.

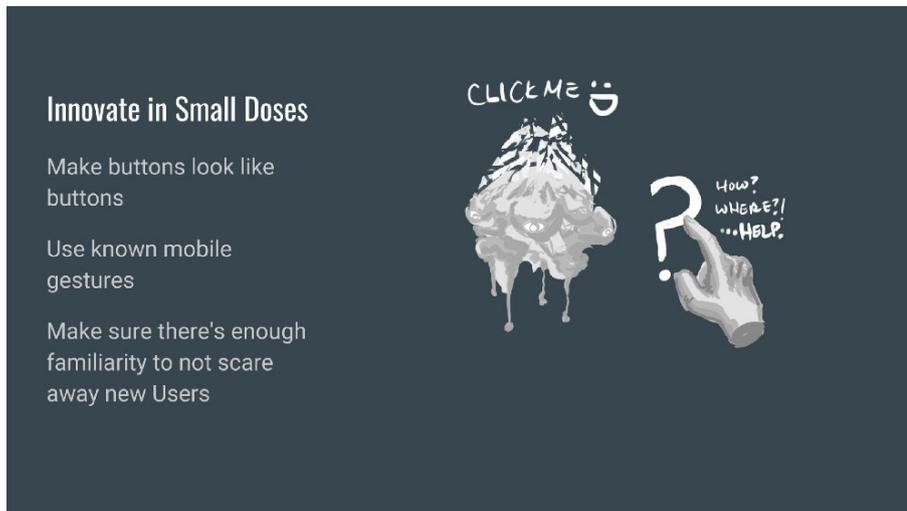
When a user wants to quit the application or do other irreversible actions, a pop-up message could be attached to the viewport to notify the user of this.



What are UX design guidelines for mobile Augmented Reality?

Accessibility

Onboarding for AR is important, because it is a new technology. It has a 3d space, which makes it have a bigger learning curve. This onboarding should be done by letting the user learn by doing. This means that instead of giving a manual, the user should go through the AR space to learn how the application is used.



Source: T. Wilson, 2017

In his thesis van de Water (2018), also concludes that when designing a mobile AR application, specifically it's user interactions, the designer should gradually introduce the technology. He states that a designer should add interactions that encourage movement. This in turn guides users to a deeper and more immersive experience, in which the added value of AR shows.

Hierarchy

With AR, it seems like the physical world is your limit, but the limit is actually the screen.

Users will not want a cluttered screen as their attention will be on the experience at hand. Consolidate and consider hiding information into a menu, like a simple burger menu (Ayhan, 2017)

Confirmation

Use audio and haptic feedback to enhance the immersive experience. A sound effect or bump sensation is a great way to confirm that a virtual object has made contact with a physical surface or other virtual object. In an immersive game, background music can help envelop the user in the virtual world. (Apple, 2019)

Consistency

An important part of a mobile AR experience is that it uses the whole screen for the AR part. Both the apple and google design guidelines cannot stretch this enough.

Make text visible and easy to read by making it large and making smart font choices. San Serifs can be easier to read than Serif fonts depending on the context. Use the same amount of text (or less) as used on a traditional mobile interface.

User Control

It is important to keep the experience refreshing but predictable. A user does not want to learn a whole new set of interactions.

Make the controls easily accessible by one hand.

When interacting with object, do not control them with onscreen controls, instead put the controls in the AR space.

How can these be used in AR for wearables?

The biggest difference between mobile AR and AR wearables is the clear boundaries mobile AR has. An AR wearable does not have these clear boundaries, so the user cannot really see where the FOV ends. This might make building an immersive experience harder, because of the chance that virtual objects that are too big will be cut in half.

Use visual and audio cues for feedback is important, because AR is a new way of interaction. If the users see how the 3d world reacts to them, they learn faster how it works.

A menu must not be in the viewport, because it will obstruct the user's field of view, especially when using an AR wearable, where the field of view is small. The menu should be called by using a tool or should be attached to the user in a way that it is not in the way.



What are UX design guidelines for Virtual Reality?

Accessibility

VR apps with intuitive user interfaces, similar to what people use on their wearables, phones, tablets and computers, are what will make VR accessible to the masses. Novel interactions are fun to come up with, but it increases user's learning curve. (Hudelson, 2018)

It is important to design an experience that is comfortable for the user. A user can get fatigued or nauseas by using a VR headset too long.

Text instructions don't perform well in virtual reality for a number of reasons. Small text is hard to read. Users are often overloaded with visual information from the virtual environment around them. Consider including short audio summaries instead to provide users with instructions. (Google, 2018)

Hierarchy

Similar to designing 2D interfaces, designers should use size, contrast and color to denote hierarchy. In VR, size is based on the distance between the user and a piece of content, so it's important to understand the scale of content and appropriate viewing distance. (Hudelson, 2018)

Tools and UI should be clear and easy to use but implemented so they don't distract users when they don't need them. (Jaime, 2017)

Confirmation

Audio and haptic feedback inside the VR experience are as important as the visual experience.

Consistency

Gestures should be meaningful in order to avoid simulation fatigue. Beware of metaphors, accommodate the extraordinary. Users still want to have that effortless experience, but there's still value for extraordinary experiences. (Malai-ka, 2015)

User Interface (UI) elements should be placed a comfortable distance away from the viewer. Elements that are placed too close (including text, weapons, and tools) can cause eye strain due to vergence-accommodation conflict. Accounts differ, but recommendations say keeping UI between 1.3 meters and 3 meters. The UI should fit in the middle third of the viewing area as it is difficult for people to swivel their eyes in their sockets. (Jaime, 2017)

User Control

Every platform has different methods to engage with the VR environment. For example, Google Cardboard has only one button, Oculus and HTC Vive both have two hand controllers which provide six degrees of freedom. The controllers enhance the VR experience by allowing users to pick things up and physically engage with the others.

How can these be used in AR for wearables?

The placement of menus is important in VR, because there is no set boundary or distance for where the menu needs to be placed. AR for wearables faces the same problem, so it is best to keep those menus at 1.3 to 3 meters. VR and AR for wearables have a lot of similarities. The biggest difference however, is that AR wearables need to take the real-life environment into account, whereas VR does not need to do that.

It is evident that VR has the same problem as AR wearables when looking at the way of control. There is no set of guidelines on how to control, so there are a lot of different controllers flooding the market.

How to test these design guidelines?

To find guidelines for AR wearables, a contextual prototype had to be made. A contextual prototype means a prototype made from a concept with a specific customer segment. The customer segment that was chosen, were office workers. This had multiple reasons:

- The stakeholders are office workers, making it easier for them to project themselves into the customer segment.
- The technical limitations of the Magic Leap (works best inside, not very reliable)
- Testing the prototype is easier in office (expensive, crash sensitive)

This contextual prototype needed to show how the future with AR wearables could look, so first a survey was made to get to know the pains & gains of this customer segment and where AR could help to improve the work within office. Out of these a user story was made which encompassed multiple interactions.

During testing, the novelty effect should be taken into account. The novelty effect is when users are exposed to a new environment or system, they get a short performance boost. (Klosowski, 2014) After a given time when the novelty effect is over, the users view on a product can change. When testing the Magic Leap, nearly all testers have not used the device before. To see if the novelty effect is evident, testing should be done with a group that tests every iteration and another group that is new every iteration.

Where does augmented reality on wearables differ from the other products and how does this influence elements?

The real field of view is hard to keep track of. There is no clear boundary on where the field of view ends. With other devices, there is a clear canvas to work with. On AR wearables the whole environment can be used as a canvas, but the part that gets rendered inside the FOV is small, so it is unclear where boundaries are.

Unlike most other products, except for everyday objects, AR wearables must take the environment into account. To have a good experience, boundaries must be set in the environment worked in. By using physics on objects and environmental scanning, losing digital elements because they are stuck 2 meters underneath the ground can be avoided.

There is a minimum range of things to get rendered, things should be 40 cm away from the wearer. Everything between 0 cm and 40 will disappear, because of the limitations of the AR wearables.



Results

To get a good overview of the results from researching UX guidelines on other products, a table was made to look where multiple principles overlapped. This could result in AR wearables needing the same functions. The table was made with taking in account the knowledge of an average person on said products.

	Real-life objects	Desktops/laptops	Smartphones	Mobile AR	VR
Accessibility	Defined by affordance	No onboarding required when using well known functions	No onboarding required when using well known functions	Onboarding Required Learning by doing	Onboarding Required Learning by doing
Hierarchy	Self-explanatory	Main function in centre, sub functions mostly in top of screen Navigation should always be visible or at same location	One primary function per screen Navigation should always be minimized in burger menu and visible or at same location	Main-function Fullscreen Navigation should be minimized in burger menu.	Full screen of surroundings Tools and menu should be minimized or invisible and show up when called for.
Confirmation	Visual & Audio & Haptic feedback Instant feedback, no warning.	Visual & (Audio) & Haptic feedback Pop-up warning when performing irreversible action	Visual & (Audio) & Haptic feedback Pop-up warning when performing irreversible action	Visual & Audio & Haptic feedback Pop-up warning when performing irreversible action	Visual & Audio & Haptic feedback Pop-up warning when performing irreversible action
Consistency	Defined by affordance	Maintain simplicity Typefaces, colours, controls should always remain logically consistent	Maintain simplicity Typefaces, colours, controls should always remain logically consistent	AR must always be Fullscreen	Menus should be far away enough so the user can read it easily
User control	Defined by direct manipulation	Mostly with precise control via pointer and keyboard	Controls accessible with one hand	Controls accessible with one hand	Many ways of control (Depends on device)

Accessibility

Because AR wearables are a new technology, it is required to make new users aware of the capabilities of the device. The way to do this is to have objects explain what they do on every possible interaction, or to have a voiced tutorial explain along the way. Also, an onboarding should be provided to get users set up for the new application. This could be done with a tutorial.

Hierarchy

The Field of view of the AR wearable is small with only 50 degrees (Magic Leap). This FOV should be used fully for viewing surroundings and showing the main function of the application, like with mobile AR. A menu should be callable by pressing a button of a controller or should be mounted on the user in a place that it is not blocking the view, like an arm mounted menu. These menus should be small enough to fit into the FOV in its entirety.

Confirmation

Like with all other products checked, it is important to have 3 ways of feedback: visual, audio and haptic. The visual feedback is done by colour-change, position-change or opacity change. The audio feedback could be done by playing audio-files on interaction. Haptic feedback, however, is really dependant. When using a controller, it could vibrate on interaction. But when only hands are used this cannot be achieved at this time.

Irreversible actions, like quitting without saving should always be done after the users are given an alert of the consequences of their actions.

Consistency

The menus inside AR should always be at a distance that is not too close, nor too far from the user. These menus are locked in the world space instead of being locked to the viewport of the user. This is necessary because for now, the heart pulse of the user makes the menus vibrate and difficult to read.

Black must never be used when designing for an AR wearable, because the wearable cannot render this. As with other products typefaces, colours, controls should always remain logically consistent.

User control

As seen with VR, the controls for AR wearables are not yet defined. Every different AR wearable device has different ways of control. It is far too early to tell which of these controls will become dominant. Most devices try to implement hand-tracking, but it works semi-ideal at best. But as seen with smartphones, when given time, a dominant way of user control will emerge.

For now, the hand-tracking of the AR wearables is fatiguing, because for this to work, the hand must be in the FOV of the device. While these are still small, the hand has to be in front of the user, which makes it tiring to do. If the FOV will become bigger, the hand-tracking will become a more viable option of control.

In case of the Magic Leap, the supplied controller is deliberately there to counter the fatigue the user could get from only using hands and the inconsistency of the hand-tracking.

To get on par with the intuitiveness of interacting with real-life objects, the technology of AR wearables must get better.

Do these results correspond with guidelines found for Magic Leap and other AR wearable devices?

After studying the manual of the Magic Leap and the HoloLens, it became evident to me that the manual of the HoloLens is far more extensive. The Magic Leap manual only describes design guidelines as vague best practises, where the HoloLens manual also describes why these are the best practises.

The user control on the Magic Leap is mainly done by using the controller, because this is the most optimized tool. The controller has 3 buttons and a touchpad, which according to the manual each have a clear goal in the building of the application. I tried to remain true to these goals, but as an application gets more ways of interaction, it gets harder to map these.

The Magic Leap manual also urges developers to warn users when an action they are doing is irreversible. But it also states that the user should not be overloaded with confirmations they do not need. Multiple ways of giving feedback is also advised, although the manual does not state the best way of giving feedback.

To conclude, the Magic Leap manual gives a lot of best practises, but it mostly does not explain why these are the best practises. By testing the Magic Leap, I became aware that many best practises are there to cover the limitations of the AR wearable. One example is that according to the manual, objects should be placed 1.5 meters away to reduce eye strain. This may in part be true, but on the other side, the minimal rendering range for the Magic Leap is nearly 40 centimetres. This makes it impossible for a user to see an object from close. This in turn reduces immersion.



Conclusion

It is important to know the ins and outs of the device being used. At the moment each AR device has its own specifications, which make setting up general guidelines hard. However, there are a couple of conclusions that came from the research into other products.

By using the 5 UX principles when considering building an AR wearable application, a lot of beginner mistakes can be prevented. There is some overlap between multiple products and AR wearables can be seen as a combination of those. Research in VR proved to be very useful, as the 2 technologies are a lot alike. The biggest difference between the two is that AR wearables must take the environment into account, whereas VR does not and that gives it much more freedom in creation.

The guidelines on AR wearables derived from the other guidelines should be taken with a pinch of salt. The AR wearable technology is evolving very quickly and the limitations that are now being worked around, could in the future be solved. Especially, user control suffers from device limitations. If an environment can be controlled at ease, it will result in a more intuitive and immersive experience than an AR wearable can offer now.

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