The XXR Tool

XXR: Further Extending Extended Reality with Sensory Perception

A graduation by Wo Meijer

Acknowledgments

Thank you to my friends and supervisors at Mobgen | Accenture Interactive.

Thanks to Wolf and Elif for being kind, patient, and most importantly signing off on my crazy ideas.

Thanks to everyone who helped me in ways big and small.

Thanks to Jaime and Fred for being my best friends.

Thanks to Anna.

01 Introduction

“The beginning is the most important part of the work.” -Plato

Graduation Goal

The goal and scope of this graduation changed many times before it began and while it was running. However, as this is the final report, its state is fixed.

The goals of this graduation were to:

- Develop a design tool that helps designers add additional senses to augmented and virtual reality project.
- Test that tool using designers at Mobgen | Accenture Interactive.
- Build one of the resulting concepts as a fully functioning demo.
- Test that demo.

In short, these goals were all achieved. Readers with more interest can read the longer summary below. While very interested readers can attempt to read the entire report.

Summary

The project followed an eight phase structure as shown in Figure 01.1.

Phase 0: context.

This project expands eXtended Reality (or XR) with senses beyond sight and sound. Several companies have promised projects that use other senses however, little has materialized.

One of the examples of XR being implemented in a wide scale is with haptics in phones and wearables. It's the opinion of the author that this extends the "haptic space" of the users' world, and thus falls under XR.

Phase 1: research

Two researches were conducted: the first on senses, the second on design tools that are currently in use. Despite what many think, humans have more than five senses. Additionally, senses work together to create "sensations" that humans use in their perception (take for example the sense of direction). People are also people, thus their perception is susceptible to odd quirks and peer pressure.

Looking at four design tools: inSights, IDEO Method Cards, Google Design Sprints, and Conversational UI Design reveals four similar elements that each use to help guide and support designers. These elements are: activities, segmentation, path, and examples.

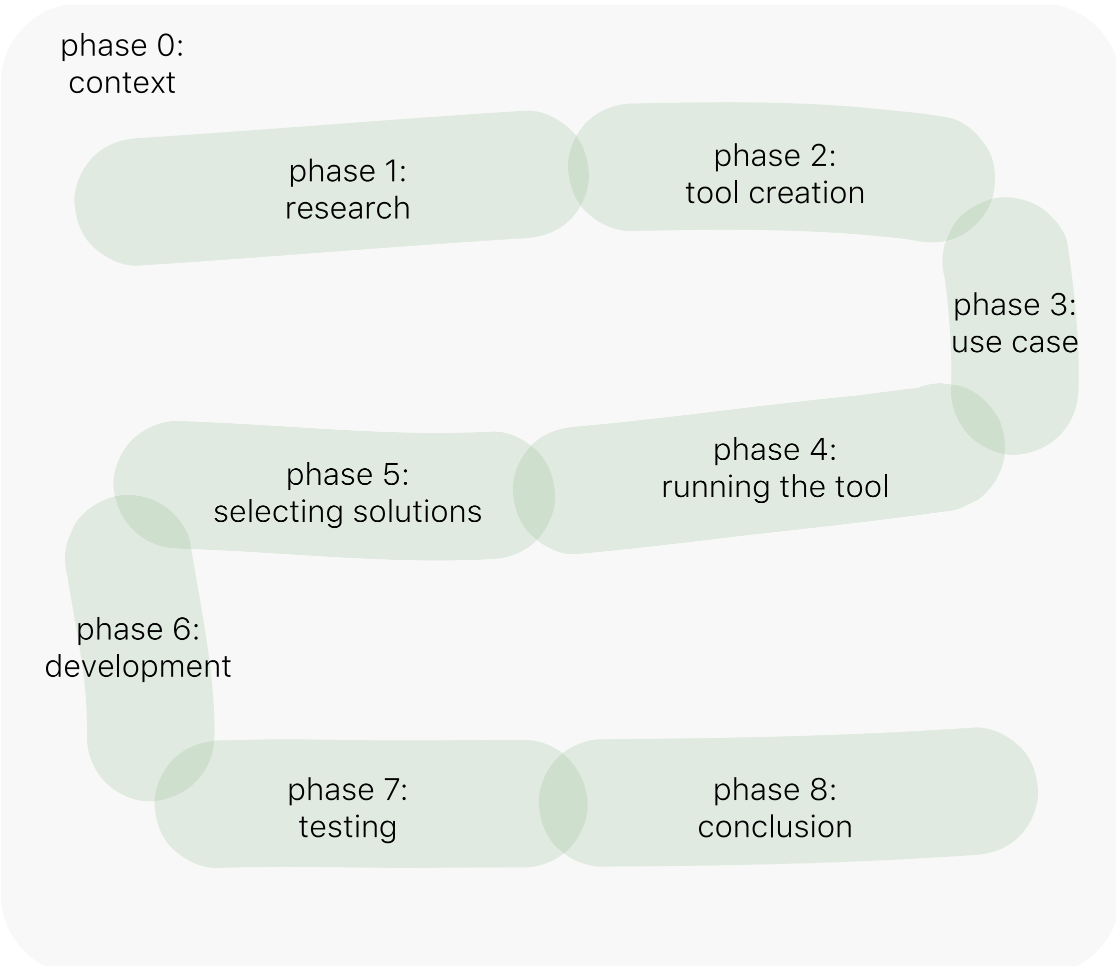


Figure 01.1: The 8 phase structure of the project and thus the report.

Phase 2: the XXR tool

The XXR tool uses these elements to help designers create a concept that uses one of the senses or sensations. Designers follow six steps: define, rate, select, ideate, modify, and synthesize. By running this tool, designers not only have a better understanding of their project, but also a well documented concept.

Phase 3: use case

ICU nurses face a very tough work environment that presents many opportunities for improvements both the lives of nurses and their patients. Two specific issues are: finding the cause of alarms in the dark, and helping nurses in training know the level of urgency of alarms. Both of these issues were discussed with nurses at Erasmus Medical Center in Rotterdam.

Phase 4: running the tool

Using the two aforementioned use cases, designers at Mobgen | Accenture Interactive ran through the XXR tool. Both trials lead to several improvements in the XXR tool itself. The trials produced two concepts: a glove that uses haptics to help nurses feel what equipment is raising an alarm, the other a foot mounted device that uses vibration and heat to convey the urgency of alarms.

Phase 5: selecting solutions

Based on the demo-real world fit, possible risks, number of senses used, and idea of transferring emotion rather than just information, the second concept from phase 4 was selected. In order to simplify development and increase usability: foot mounted became wrist mounted, and vibration would come from oscillating pressure rather than vibrator motors.

Phase 6: development

Using metaphors given by nurses at EMC; urgency levels were given a physicalization using vibration and temperature. A wearable was created using a commercial blood pressure cuff and a Peltier element. A VR mockup of an ICU room was developed using Unity. This was connected to the wearable using WiFi.

Phase 7: testing

Sixteen participants tested the wearable by first experiencing alarms without additional senses and rating the perceived urgency, then experiencing the alarms with the additional senses and rating the perceived urgency.

The highest level physicalization did not make a clear difference, however, testees were much more able to distinguish the urgency of the first two levels using the additional senses. Additionally, the testees noted an increase in immersion and felt like the alarms were personally addressed when additional senses were used.

Phase 8: conclusion

This section contains a few thoughts on the process and my achievements in the graduation process.

XR and XXR

XR: eXtended Reality- Extending the user's reality is extended using hardware and software. See Figure 01.2.
XXR: eXtended eXtended Reality- XR that uses senses besides sight and sound.

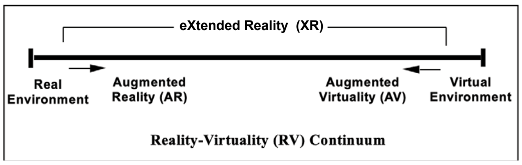


Figure 01.2: the RV Continuum defined by Milgram et al, 1994.

XR Now

Currently, most XR focuses exclusively on augmenting the user's perception of sight and sound. These two senses are both easy to augment and are responsible for a great deal of a user's total perception. An example of a project in this space is the ubiquitous Pokemon Go, which enables the user's phone to augment the user's sight (overlaying visual information on the screen as seen in Figure 01.3), and the sounds in the user's environment (by playing audio on the phone's speakers).

Figure 01.3: A screenshot of Pokemon Go showing a Pokemon overlayed on top of the user's view of the world. (Niantic and The Pokémon Company, 2019)

XXR Now

There are two different types of XXR projects: HCI research projects, and unverified start up projects.

HCI research is mostly foucsed on the neuroscience driving the interactions and interpretations of different senses. These projects are often overlooked by the designers who could utilize these findings to improve user experience.

The second category Extended XR projects that are currently around consists of non-materializing start up projects.Take for example ChatPerf: a Japanese company that attempted to create an add on for the iPhone that would allow the augmentation of smells in the environment (see Figure 01.4). However, like many XXR projects it never materialized.

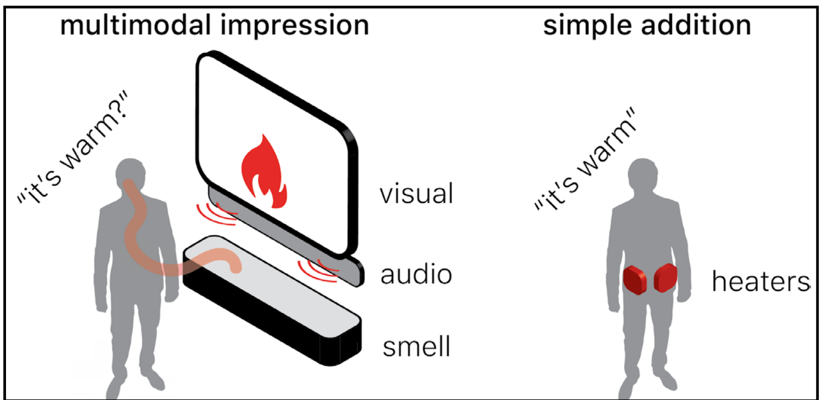
MultiModal Interplay

Human perception is by blending many different sensory inputs. It means that it is possible to emulate certain sensations by feeding the user sensory inputs that support the desired reaction. The XXR tool focuses on adding senses directly. This way, designers can create meaningful impact for the user with less effort and uncertainty.

That is to say, if the goal of the designer is to have the user feel an increase in temperature, then the method for achieving that is simply heating up the user. In opposition to this, it would be possible (although difficult to implement and uncertain) to give the impression of heat using a combination of other senses (for example sight, sound, and smell). This difference is visualized in Figure 01.5.

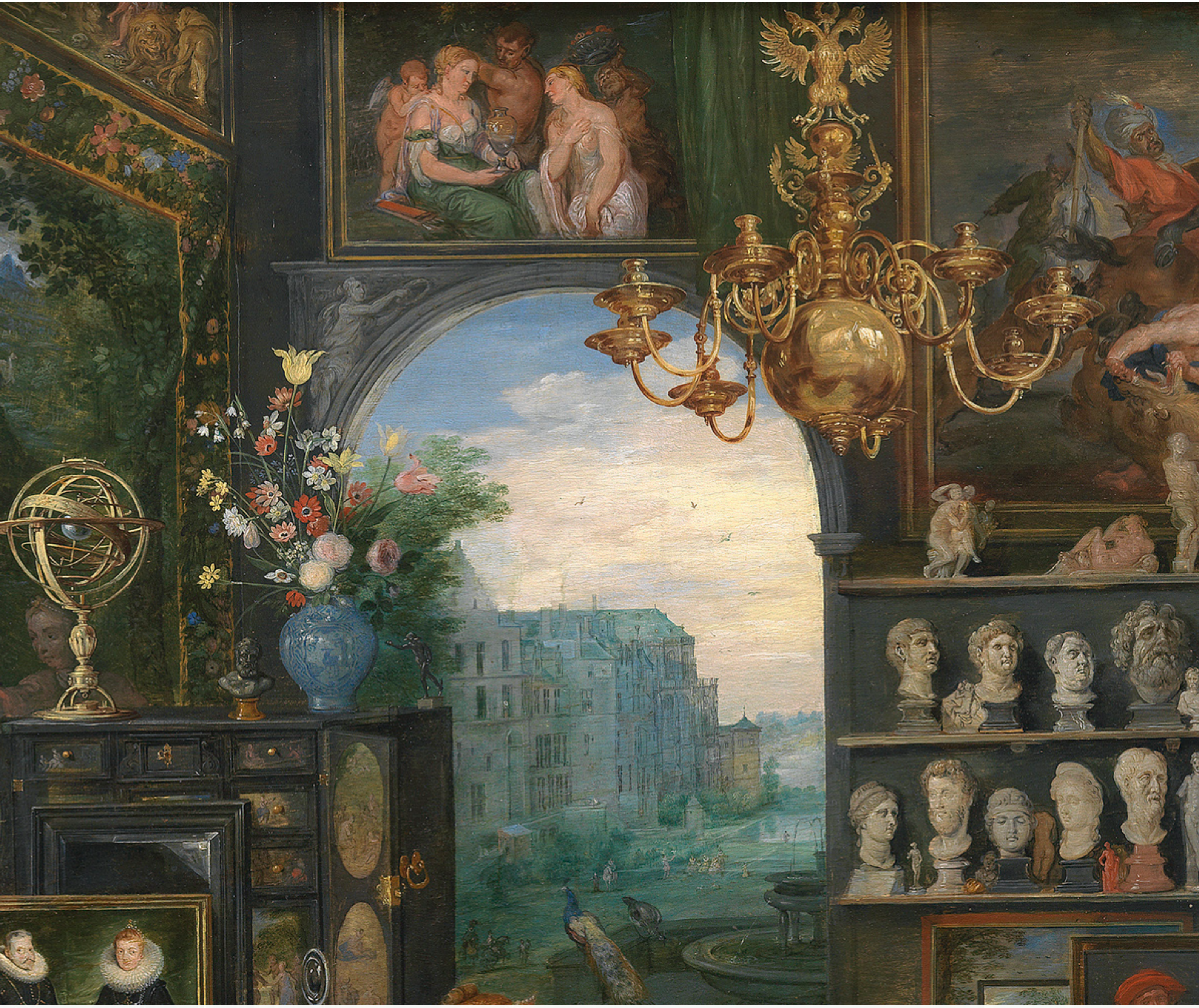
(below) Figure 01.4: the ChatPerf, a device that allows a phone to augment the smell of an environment.

Figure 01.5: Two methods for altering the user's perception, the left using multiple senses, the right using a simple method for directly targeting the sense responsible for the perception.



11 Senses, Sensations, and Humans

"That there is no sixth sense in addition to the five enumerated-sight, hearing, smell, taste, touch…" - Aristotle



Introduction

As defined by the Merriam Webster dictionary a sense is "the faculty of perceiving by means of sense organs" however, it is also defined as "a particular sensation or kind or quality of sensation", or even as "a discerning awareness and appreciation". These definitions touch on a core flaw in our language and perception of what a sense is. We equate sensory organs such as touch with the sense of direction or sense of time.

Levels and Abilities

In order to help understand and select senses, it's important to create a distinction between senses, sensations, and the influence of psychology. These different levels are adopted from the classifications of Proctor and Proctor (2012)

Sensations are forms of perception that are not the result of a singular sensory organ, but combinations of several inputs. An example of a sensation is wetness, which is known to be a learned interplay between the sense of temperature and the sense of touch (Bergmann Tiest, 2012).

In addition to senses and sensations there are the influences of human factors. This is refers to changes in perception that occur because of the nature of human beings (such as heuristics in decision making (Gigerenzer, 1991) or optical illusions(Coren & Girgus, 1978)).

Beyond these senses related to personal perception, there is also Social Perception (or how the behavior of others changes the perception of an individual). These effects are complicated, can differ wildly between individuals, or at the very least need to be taken on as a case by case basis. Considerations of these effects and the possibilities of how to influence them given sufficient technology is discussed at the end of this section.

Ranking

Each sense is rated on several characteristics that are crucial to make a selection. The characteristics are as follows:

- Fidelity (how much bandwidth and or realism is provided by the sense)
- Scalability (how difficult and expensive is it to produce)
- Usability (how easy is it for a designer to develop this sense)
- Speed (how quickly can the designer chance the input)
- Subjectivity (how much the input depends on the user)

Characteristics are estimated based on the example projects. Each sense has its own context in which it works well or not at all, thus, when selecting a sense, a designer must ensure that the context of their user fits the sense and in turn that the sense fits the context.

Sensations and human factors are significantly more dependent on the implementation, users, and context. Thus the ranking should only be taken as a general comparison between senses at the same level.

Senses

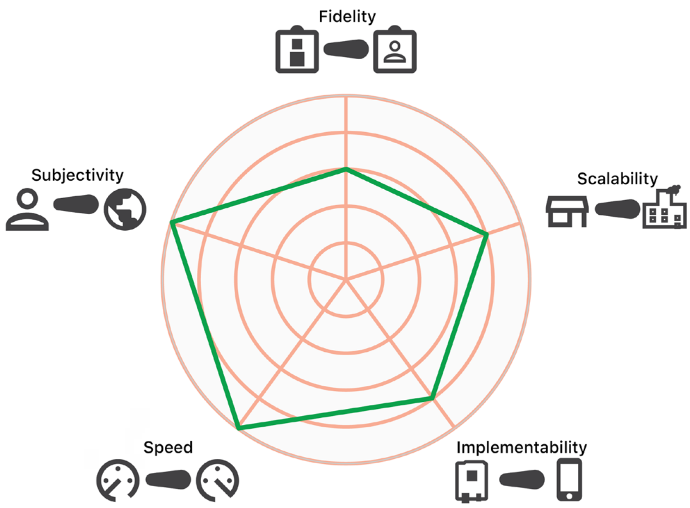
Each of the senses have a sensory organ or nerve ending that allows the brain to receive this information (Lawson, 2013). The senses covered in this section are compiled from both Lawson, 2012 and Proctor & Proctor, 2012. However, sight and sound are omitted due to being out of scope for this analysis (which aims to add additional sensory interactions) as well as pain, as it is not ethical to use. A number of other senses (such as hunger) are also omitted as they are not 'accessible' to designers.

For the sake of the reader, three select senses are presented; vibration, pressure, and smell. The other senses listed below can be found in Appendix 901.

The senses are as follows:

Vibration
Stretch
Pressure
EMS
Temperature Local
Temperature Global
Balance
Smell
Proprioception

Vibration



Description:

Vibrations are mechanical oscillations of force applied to the skin. This is usually done via vibration motors or linear actuators placed on the users' skin. This sense is often used in HCI projects and can be found as a simple, low fidelity solutions such as in cell phones. However, more detailed information can be shared using multiple motors and spatiotemporal mapping (Novich and Eagleman, 2015)

Examples of use:

Using space and time to encode vibrotactile information: toward an estimate of the skin's achievable throughput (S. Novich and D. Eagleman, 2015)
Feeling Speech on the Arm (J. Chen et al, 2018)
Tactile Feedback at the Finger Tips for Improved Direct Interaction in Immersive Environments (R. Scheibe et al, 2007)
The Development Of An In-hand-haptic-feedback Device Based On Magnetorheological Fluid (T. Eftling, 2012)

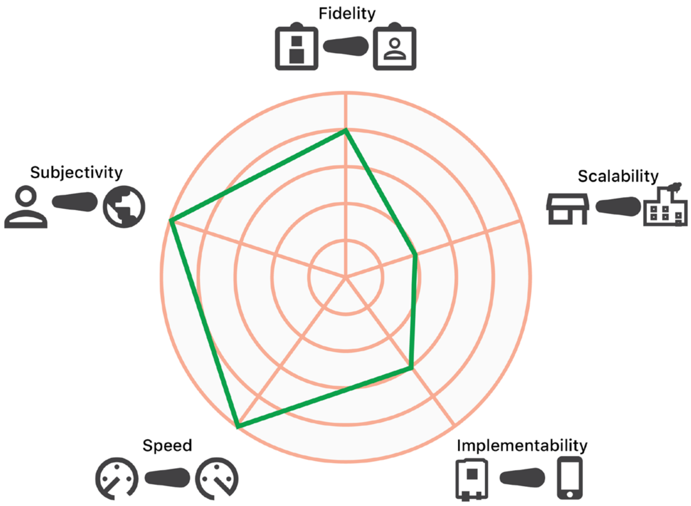
Notes:

Vibration is a low cost, low barrier method of sensory manipulation.
Vibration could be used to manipulate the texture felt by the user, however this would require extreme precision and timing.

Pressure

Description:

Pressure is a force exerted over an area of the skin, again part of the somatic system, with highly sensitive receptors on the fingers and lower sensitivity receptors on the rest of the skin (Pruves, 2012). Since the higher sensitivity receptors work together with vibration and stretch to from the perception of texture (Z. Quek et al, 2014), this section focuses on pressure as in squeezing the body.



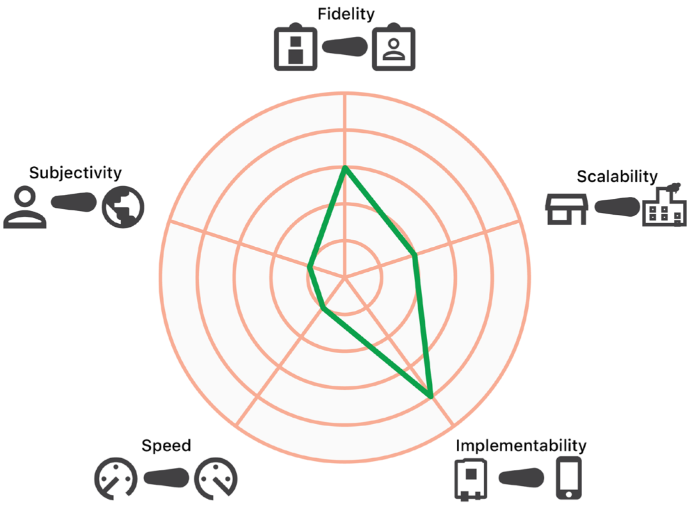
Examples of use:

Affective Haptics: Current Research and Future Directions (A. Mohamad & O. Hussein, 2012)
Affective Haptics in Emotional Communication (D. Tsetserukou, A. Neviarouskaya, H. Prendinger, N. Kawakami and S. Tachi, 2009)

Notes:

It is possible to seriously injure the user with a pressure based system, caution must be taken especially when dealing with people in a weakened state.
Speed and usability greatly vary with the actuation method and set up of the system.

Smell



Description:

The human sense of smell is a complex mechanism that recognizes certain rich combinations of chemicals (Proctor & Proctor, 2012).
Unfortunately, no "base elements" of smell have been able to reproduce arbitrary smells. Thus, systems are limited to whatever smells the designer puts in them to begin with.

Examples of use:

An Unencumbering, Localized Olfactory Display Y. Yanagida et al, 2003
SensaBubble

Notes:

The reaction to certain smells is extremely subjective as it triggers specific memories. Thus extreme awareness of the users and their context must be applied when developing smell based systems.

Sensations

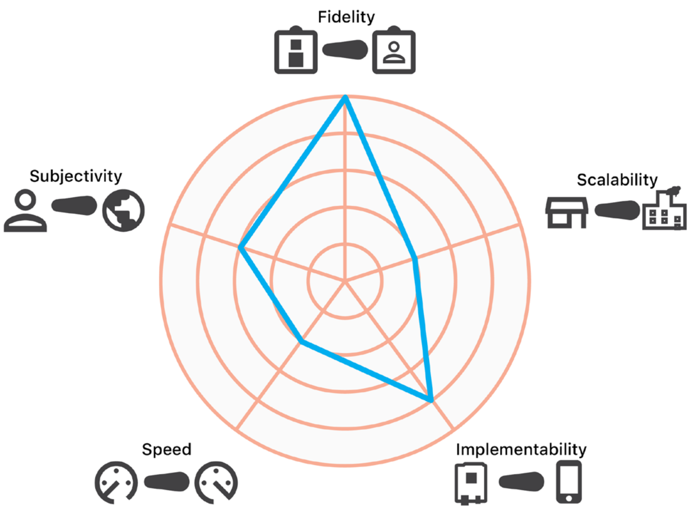
So called "sensations" combine input from various sensory organs and enable deeper levels of perception. For example, the misnomered "sense of wetness" has no defined organ; it is a complex combination of the sense of touch and the sense of temperature (Filingeri et al, 2014).

This list of sensations is not complete, but merely lists sensations that have were deemed manipulatable or are shown to be usable in other projects.

For the sake of the reader, three select sensations are presented; wetness, texture, and time. The other senses listed below can found in Appendix 902.

The following sensations are covered in this section:
Wetness
Taste
Texture
Time
Direction
Spatial Perception
Spatial Cuing

Wetness



Description:

Wetness is the combination of the sense of temperature and the sense of touch on a localized part of skin (Filingeri et al, 2014), and is a 'learned sense' (Bregmann et al, 2012). Because of it's combined nature, the sense of wetness is susceptible to manipulation from both temperature and touch mechanisms as well as directly (i.e spraying the user with water).

Examples of use:

4DX Augmented Cinema (with water effects)

Notes:

Wetness is difficult to control finely, as sprays are difficult to control.
Wetness can cause discomfort when used for extended periods of time or combined with other inputs.

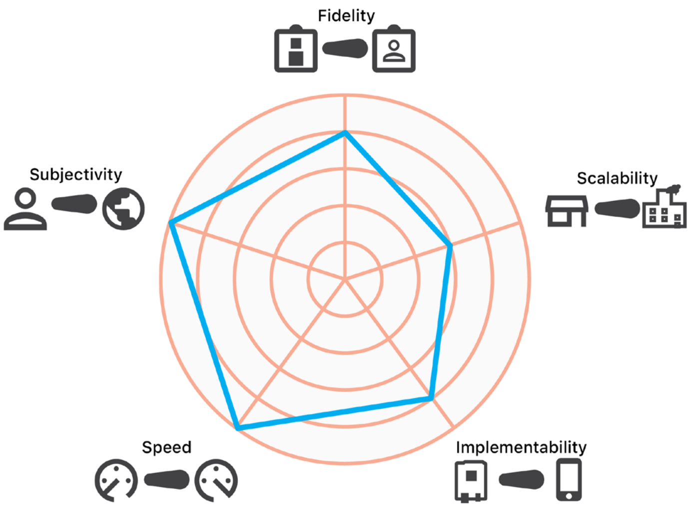
Texture

Description:

The human body uses static touch, skin stretch, and vibration when discerning the texture of a surface (Weber et al, 2013). This means that texture is challenging to replicate and can be the gap between the true and augmented world that a user senses.

Examples of use:

Sensory Substitution using 3-Degree-of-Freedom Tangential and Normal Skin Deformation Feedback (Z. Quek et al, 2014)
Weart.it



Notes:

Texture recording and playback has been accurately achieved by companies such as Weart.it, they also use visual cues (a video of someone touching the materials meant to be replicated) to help add to the illusion.

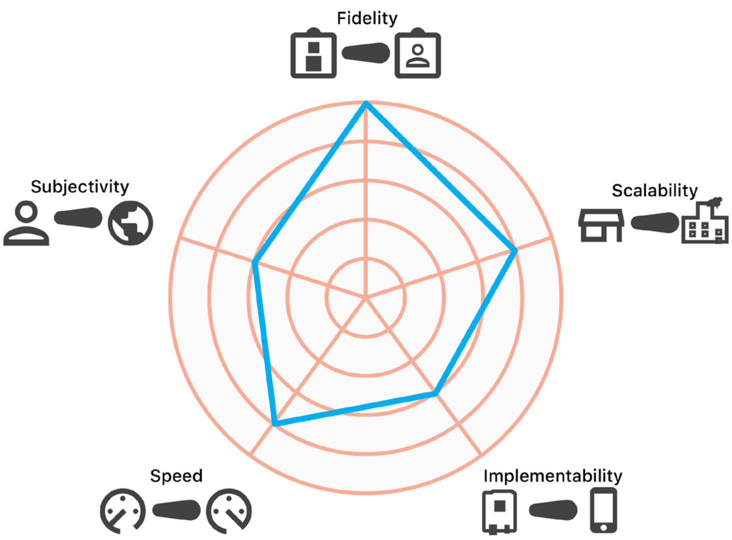
Time

Description:

Time is a massively complicated and misunderstood sensation. It includes judging duration (as seen in Wearden and McShane (1988)), rhythms (Unknown, 1936), remembering a timeline of events, and many other timing tasks.

Examples of use:

Slowing down an internal clock: Implications for accounts of performance on four timing tasks (J. Wearden, 2008)
Effect Of Virtual Reality On Time Perception
In Patients Receiving Chemotherapy (S. Schneider, C. Kisby, & E. Flint, 2011)
The Effect Of 3D Virtual Reality On Sequential Time Perception Among Deaf And Hard of hearing Children (S. Eden, 2010)



Notes:

The manipulating sense of time can be a side effect of other manipulations.

Human and Humans

While it is not the focus of the graduation, and in fact, quickly runs out of the scope of the masters program in Delft, it is important to acknowledge and document at least some of the many interesting quirks and flaws in users' perception. This ranges from simple things such as people's abilities to assume the state of reality from few inputs (for example suggesting chocolate is Swiss rather than Chinese improves the perception of the taste). In a systems approach, these so called "Heuristics" are a large part of modern studies in Social Psychology, and even in more applied works of psychology such as Nudge by Thaler and Sunstein in 2008.

The core idea of these quirks is that the brain adds to or alters the current situation the user experiences in an illogical manor. Thaler and Sunstein propose the use of these phenomenon to give what they call 'nudges' influence behavior on a macroeconomic level. However, these same heuristics can be used on a product level to influence user perception and thus user behavior and experience.

Therefore, a small collection of these heuristics are presented, along with some musing on how they might be used to influence the user from an Augmented Reality perspective. In addition to Heuristics that deal with the quirks in perception between the user and their environment, humans also have a series of quirks when they are placed amongst other humans.

While these quirks are complex, numerous, and often conflict in part, they can be incredibly powerful. With ideas as simple as adding laughter to VR having an slight effect on users' immersed presence (Ye, 2017).

Due to their inherently human nature, the following phenomenon are filtered through cultural, personal, and contextual filters. Thus they presented as possible ideas for future development and further study. It is important to know that a lot of these ideas require a subtle and realistic change in the perception of the behavior of others across all senses, making them infeasible with current VR and AR technologies.

Sense of Self

The sense of self, and conjointly the sense of identity, is a massively complex and difficult to define concept (Owens, 2006). Suffice to say, some parts of the factors that build and change the 'Self' are based on the simple senses lower down in the hierarchy. The sense of taste influences what food a person likes which then leads to their self image. Additionally, there are countless ways in which self image can be modified by Augmented Reality, from simple manipulations to complex changes in the perception of the reactions of others (more in line with the Social Human Senses).

Anchoring

Anchoring is the phenomenon whereby a person is influenced by the first piece of information they receive when needing to compare things. This is completely illogical and surprisingly powerful phenomenon (Tversky & Kahneman, 1974).

AR would not only allow for an direct artificial manipulation of numbers, but would also allow for artificial priming. For example, directly before the user is prompted to buy an app, attention is drawn to large numbers the user sees in their environment, this would set the user's anchor high and make the app seem inexpensive in comparison.

Status quo bias

Also known as defaulting, the status quo bias is the idea that users are less likely to change from the established or suggested options and/or behavior (Kahneman, Knetsch, & Thaler, 1991). This is immensely powerful in all kinds of digital and physical products, but only becomes more important as more control of the inputs of a user are given to the designer.

Conformity

Conformity is the innate human desire to fit into a group by adopting the behavior of the group as a whole and can have massive unseen effects on behavior and perception (Cialdini & Goldstein, 2004).

Selective presentation and projection of certain behavior across a group of real or virtual individuals could skew the target of what a user conforms to, influencing their behavior and their beliefs.

Imitation

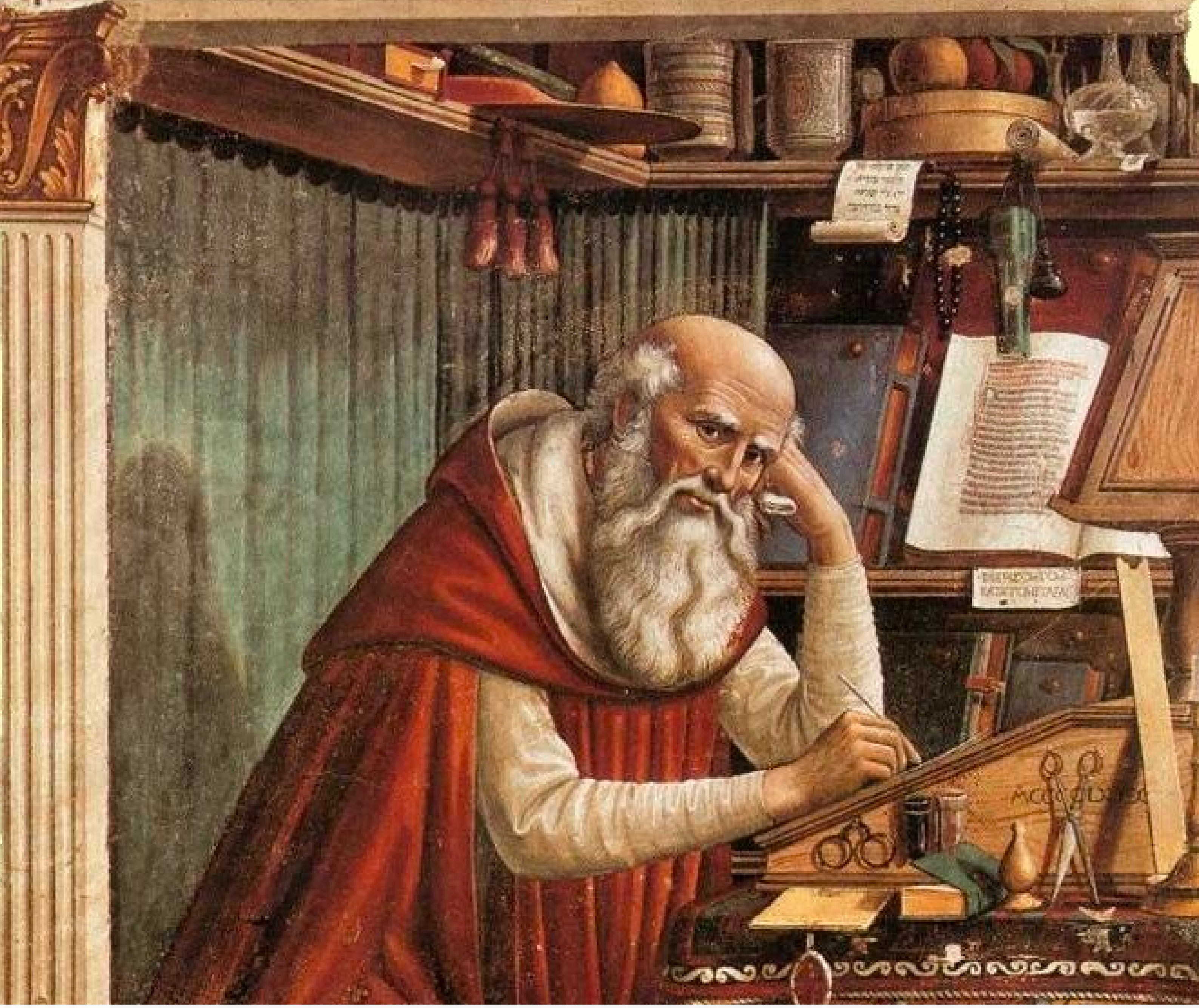
Imitation is the ability to, and desire for, copying another entity's behavior. It's a massively important tool for learning and is a major part of a person's emotional and cognitive development.(Chartrand & Bargh, 1999)

Imitation is already used in video games in order to show the user how to accomplish certain task or show them different mechanics or possibilities.

A more impactful subset of imitation is mirroring, in which part of the brain responsible for copying the actions for others takes over when the user observes someone taking a certain action in order to achieve a goal they also want to achieve.

12 Design tools

"It's not a 'how to' guide—it's a design tool meant to explore new approaches" - IDEO



Introduction

Design tools are essential to give designers the structures, skills, and methods to produce better products, services, and systems. The term “design tool” is broad and could mean anything from a Copic Marker to Adobe Photoshop to the Vision In Product design method. Thus this chapter takes several exemplar design tools that have a similar scope and style to the desired result of this graduation project. These examples are deconstructed and the common elements of all of them are discussed in order to inform the elements of the eventual XXR tool.

Examples

The following tools are a selection of interesting and noteworthy design tools used as inspiration to help guide the development of the XXR tool. These examples are:

- inSights
- IDEO Method Cards
- Google Design Sprints
- Conversational UI Design

(left) Figure 12.1 the swatches of inSights showing the two different ways of searching through them.

inSights

InSights is the result of the masters thesis of TU Delft student Wouter Middendorf, it is a design tool used to aid UX designers in the redesign of websites to help increase persuasion of user behavior. The tool is presented as a series of swatches, with each swatch represents a 'principle' of persuasive web design, while additional swatches are 'fundamentals' which define concepts that act as categories for the principles. The principle swatches feature a description of the principle, which fundamental it is connected to, and finally an example of this principle being applied in a real website.

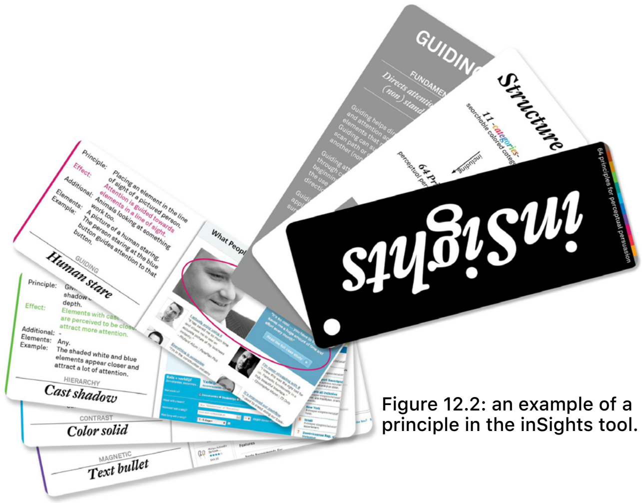
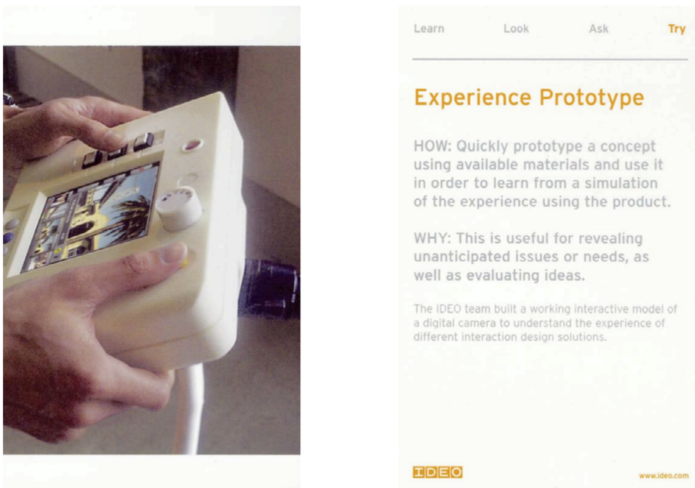


Figure 12.2: an example of a principle in the inSights tool.

IDEO Method Cards

These cards present different methods that can help inspire designers or shake up their process if they are stuck. They were released in 2003 by IDEO, a design consulting company to help spread their techniques and methods to companies. It consists of 51 cards that each present a method and an example of when the method is used at IDEO. The methods are split into a "how" that covers what the activity consists of, and a "why" that touches on the ideal outcomes of the activity. These are presented in four categories that represent different activities in the design process that the designer is trying to achieve. This way the tool can be used by in many different contexts and at different points in the process.

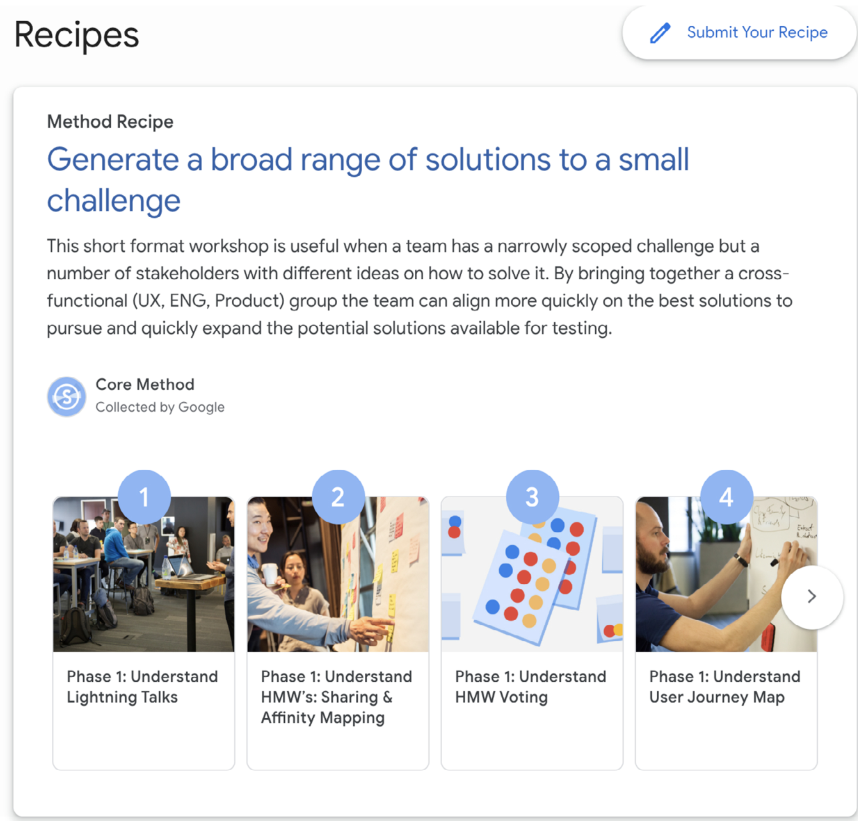
(above) Figure 12.3: The IDEO method cards in use. (IDEO)



(left) Figure 12.4: an example of an IDEO method card, "Experience Prototype" (IDEO)

Google Design Sprint

Google Design Sprints is a general design tool that has been developed based on a variety of UX design tools. It is a multi-day tool designed to be done by a team in order to generate and validate concepts for new designs or even redesigns.
It has a multitude of activities that are used for research, ideation, consensus, and validation of ideas. Unlike the other tools mentioned, GDS is presented on a website that suggests a structure, categorizes tools and provides use cases and recommended sets of tools.

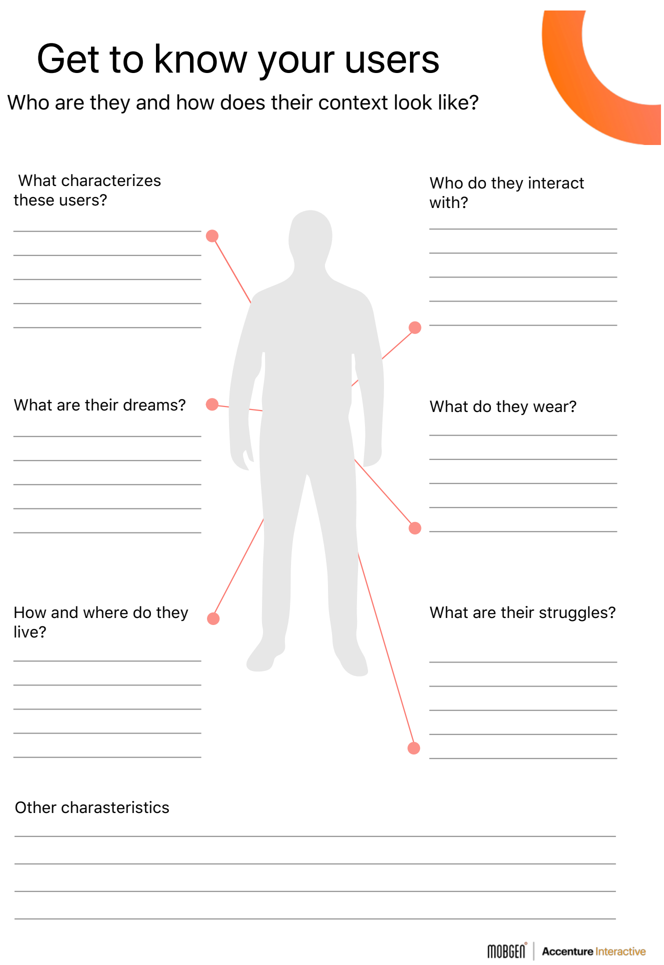


(right) Figure 12.5: an example of a recipe, or combination of activities on Google Design Sprints' website.

Conversational UI Design

This is a workshop tool created at MOBGEN | Accenture Interactive for assisting designers in designing impactful and unique conversational interactions. This is an example of a tool designed specifically for workshops that are meant to focus designers on the benefits and limits of an untraditional medium of interaction, in this case conversations.

The tool consists of four sheets to be filled in by groups of designers and guide them through different aspects of a conversational interaction. Each sheet is presented one at a time with group feedback and discussion in between each stage.



(left)Figure 12.7: an example sheets in the Conversational UI Design tool showing the activities to help define a user.

Elements to Emulate

All of these tools contain simple elements that help make an effective and efficient tool that balances applicability with depth.

For the previously discussed tools, the most impactful common elements are:
- Activities
- Segmentation
- Path
- Examples

Activities

One of the most crucial elements that allows rapid and strategic use of these tools is the fact they present many small activities that can be (re)used independently in the design and development of a project. This ranges from the completely independent activities of the IDEO method cards and inSights to the more structured activities of the Conversational UI Design tool.

Figure 12.9: inSights swatches sorted by category is an example of segmentation.

Segmentation

All of these design tools are all segmented in order to help get an overview of the available tools as well as be able to use only one part of a tool at a time.

This is best exemplified by the four categories of the IDEO method cards, each gives a description of the type of activity and even the desired action it takes (such as "try" reflecting the core idea in testing and ideation steps of a design project).

Additionally, the Google Design Sprint website takes a more experience driven look on segmentation. Recipes are sets of activities that previous designers have chosen as impactful for certain situations. These allow designers to quickly get an idea of which methods to use for their specific challenges.

Dot Vote

Core Method
Collected by Google

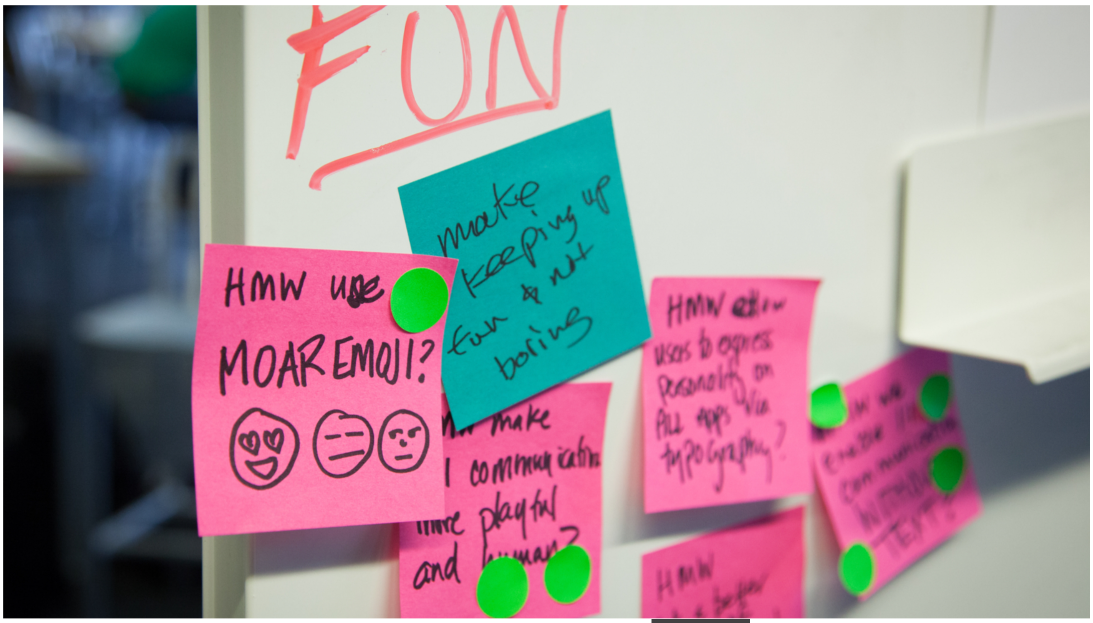


Figure 12.8: The Dot Voting activity is widely used, and this is reflected on the Google Design Sprints website.

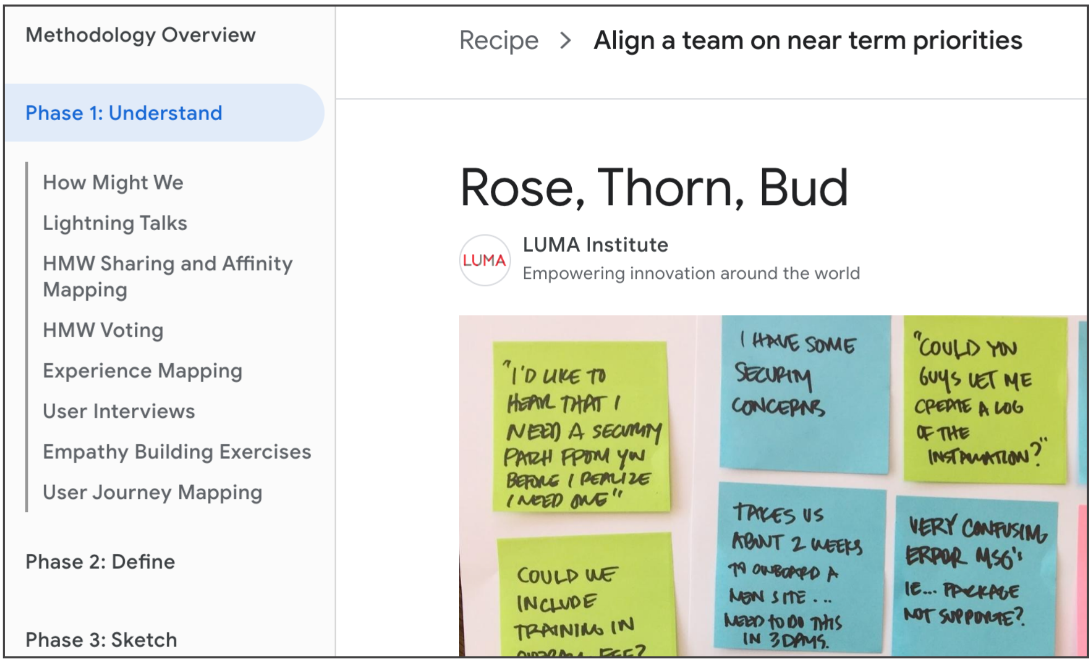


Figure 12.10: A path presented by Google Design Sprints via a recipe.

Path

While the strength of activities is their individual nature, and the idea of segmentation gives the designer a better idea of what each activity of a tool is for and when it should be used, tools can also impact the process of a project and thus be able to guide users down a path. This is key to Google Design Sprints, as it is largely meant to be utilized in full as a multi day process. In contrast, the only path the IDEO method cards suggest is in the segmentation of the methods.

Examples

One of the simplest yet most powerful elements found in these design tools is the example. These range wildly; the IDEO Method Cards only include a brief overview of how the method was applied tied in with the image on the reverse of the card. Contrasting with this, Google Design Sprints includes full case studies on their website that not only show how the methods were used, but also the results of them.

By making examples a key part of almost every sheet, inSights takes a more involved approach and shows many examples of the desired goal of a tool to inspire designers While impossible to demonstrate via paper, the Conversational UI Design tool started off with several examples of Conversational UIs and drawbacks of Conversational UIs.

This points to a very crucial aspect of an example that a design tool brings, it should match the medium in which the design takes place. This is reflected by inSights's examples being two dimensional and Google Design Sprints case studies tell the story of development and refinement of ideas.

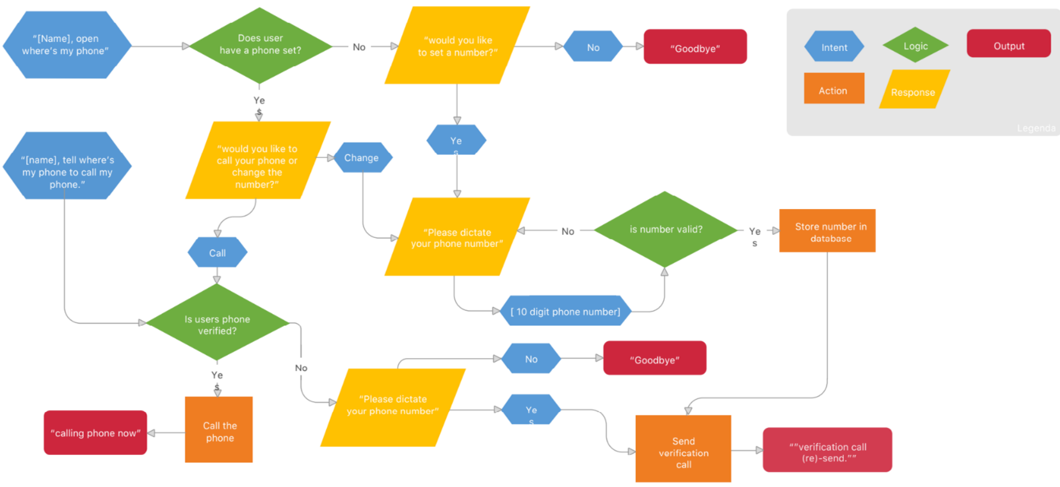


Figure 12.11: An example of dialog flow from the Conversational UI Design tool.

20 The XXR Tool

“All beginnings are very troublesome things”

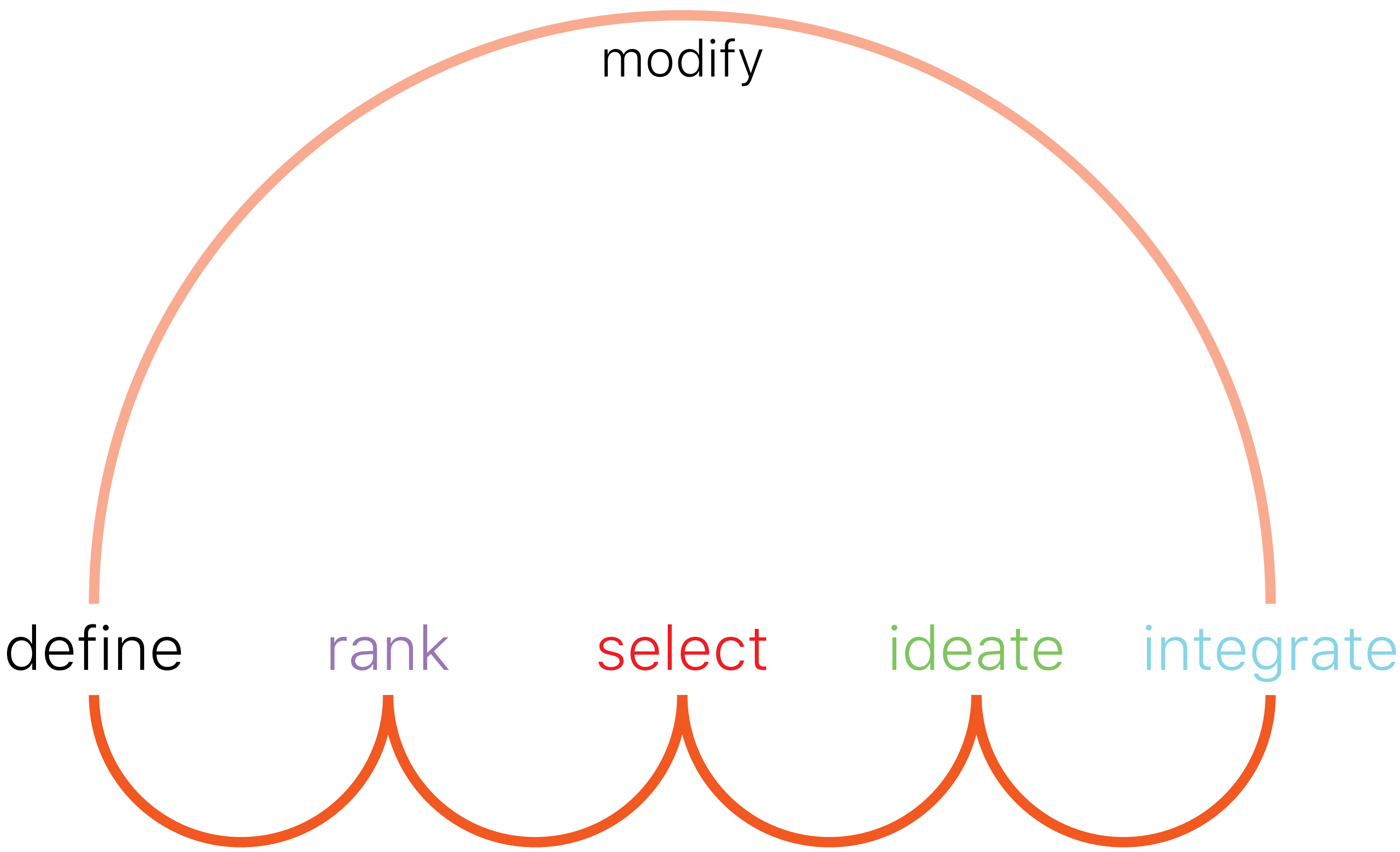
-Letitia Elizabeth Landon

Introduction

This section shows the XXR Tool as it is now. Since the moment it was created it was heavily modified after each of the two tests with designers at Mobgen | Accenture Interactive (as well as repeated small tweaks and changes after feedback from other designers and the supervisory team). For clarity, this final version is the one presented and the one found online at github.com/womei/XXRTool. For readers interested in some of the changes, they can be found at the end of each section on the running of the tool (sections 41 and 42 respectively).

The XXR Tool as it is now is a tool that helps designers think about and select different senses and sensations to add to an existing process or product. By guiding the user through the information needed to start the XXR tool, it easily integrates with existing design processes. In order to create the most impact possible, the final stage, synthesize, includes several possible methods of sharing the results of the process.

XXR tool



Define

Description

Define is the first step of the tool, and asks the designer to nail down their user and use case. This step is meant to allow the tool to hook into existing design processes as most focus on defining the user and their needs, which simply needs to be restated and agreed upon.

Goals

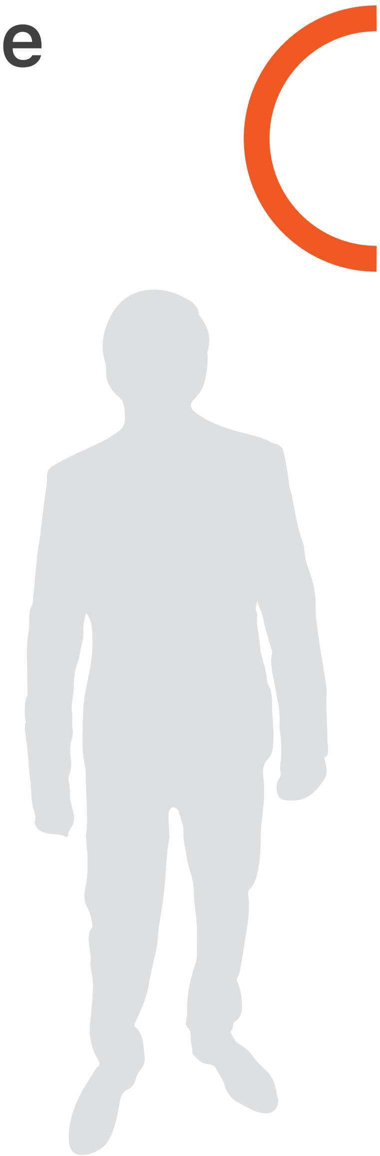
- Have a clear consensus on the idealized 'User'.
- Have a clear consensus on the Problem Statement.
- List "what they need to do"
- List "what is helpful to them"
- List "what are their struggles"
- Mark the senses/areas of the body they cannot use.

Process

First the designers must agree on a Problem Statement, essentially what the issue is they are trying to address. This is pulled from the larger design process. Following this the senses and parts of the body the user cannot use can be marked. Then Designers should take 10 minutes to write down as many answers to the three open ended questions as possible.

XXR define

what do they need to do?



what is helpful to them?

what are their struggles?

problem statement

Rate

Description

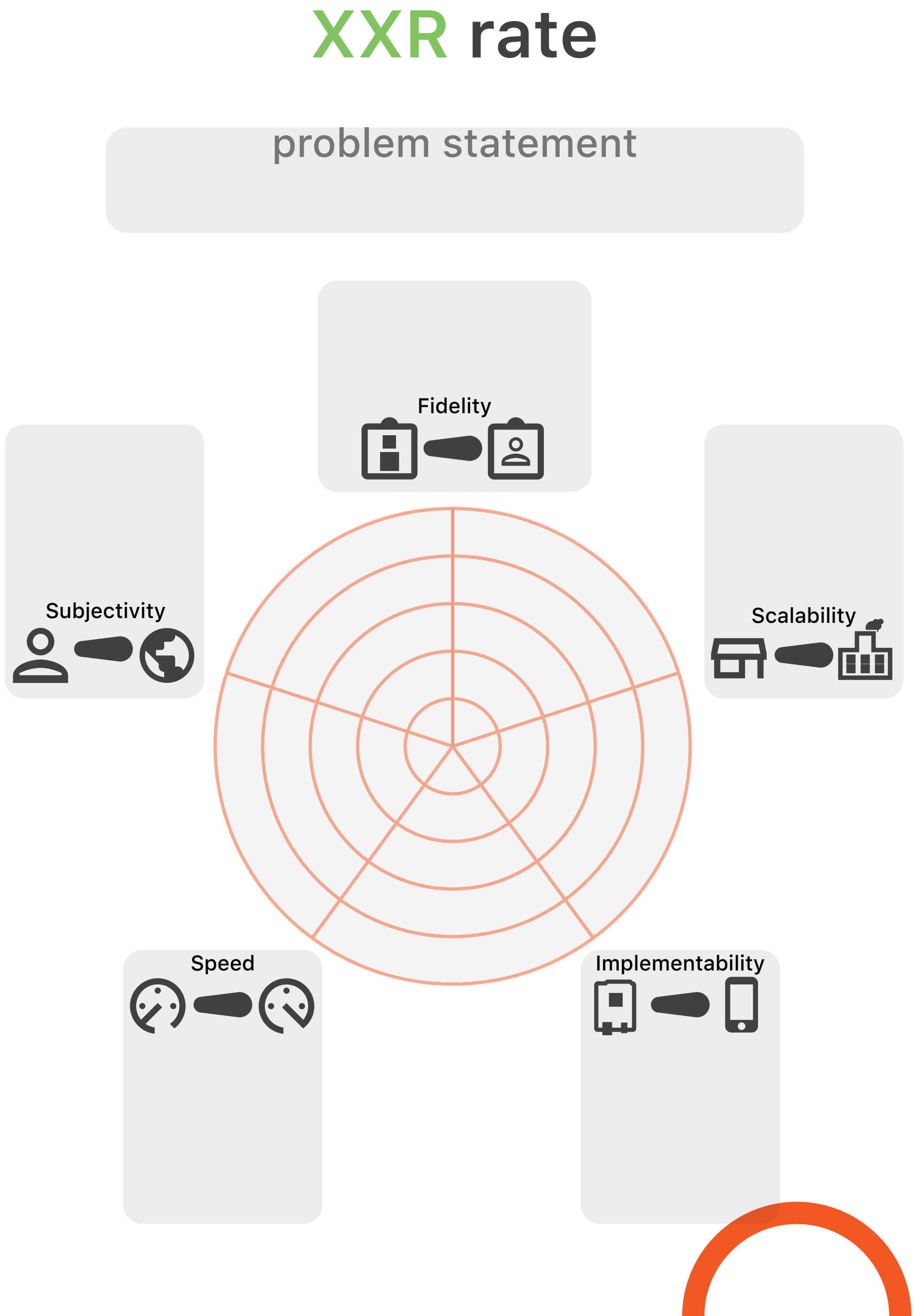
Once the use case and goals of the project are clearly established the next step is to think about how these reflect in the importance of selecting a sense. The way this version of the tool proposes to do that is by dot voting on the importance of attributes that are compiled for each sense.

Goals

- Have a clear consensus on what the three most important criteria are.
- Discuss any differing opinions in the group about the importances.

Process

Each designer gets three votes that they can place in any confieration on the list of criteria. That is to say, each person can vote for three equally important criteria, give a most important (2 votes) also important (1 vote), or express that one criteria the absolute most critical (3 votes). Following the voting, the designers total the votes for each criteria and discuss the ranking and implications of it.



Select

Description

The select step allows designers to compare all of the available senses and based on the previous rank step, inform the designers decisions in select one or more possible senses to move forward with.

Goals

- Discuss each sense possible and have a clear understanding of why it would or would not be useful.
- Decide on one or more senses to move further along the process with.
- Realize if the applicable sense have some short of shortcoming that needs to be addressed in the modify step.

Process

The designers go through the deck of sense cards and based on the presented ranking and the desired performance form the rank step, place the card on the sheet. Then the designers all go through and discuss the placement of the cards, write notes based on why the card was placed there or realizations from the discussion.

XXR select

So, of the senses...

fit super well, since...

could work, but...

won't work because...

Ideate

Description

The ideate phase is the moment for designers to get creative and find some methods of using the previously selected senses in ways that might not be initial obvious or at the very least are more developed.

Goals

- Have several ideas for ways to use the selected senses.
- Have a few more developed concepts for how to use the selected senses
- Have one or more ideas that are can be moved forward with

Process

Each designer takes one of the posters and writes the Problem Statement from the previous steps. Then they select one of the sense cards from the previous step (start with "fits super well" and move to "could work but" if there are more designers). The sense selected is also written down on the sheet.

Then each designer takes two minutes to write down, sketch, or otherwise document their idea for using that sense. Then designers pass the sheets to their left, then take one minute to review ideas written on the sheet, and then the process repeats. This goes on until every designer has filled in every sheet and the sheets are returned to the designers who started them.

Then designers take three minutes to review everything written down on their sheets and mark what they like. After, each designer gets a fresh sheet of A3 paper and takes another three minutes to write down, sketch, or otherwise document a concept based on the ideas they selected form the sheet.

Once this is done, each designer takes thirty seconds to write present their concept to the group. With all of the concepts being presented, designers take one minute to vote on their favorite using dot voting (with two dots each).

The designers then select the top (or top two or three ideas if there is a tie or close vote) concept into the Synthesize phase.

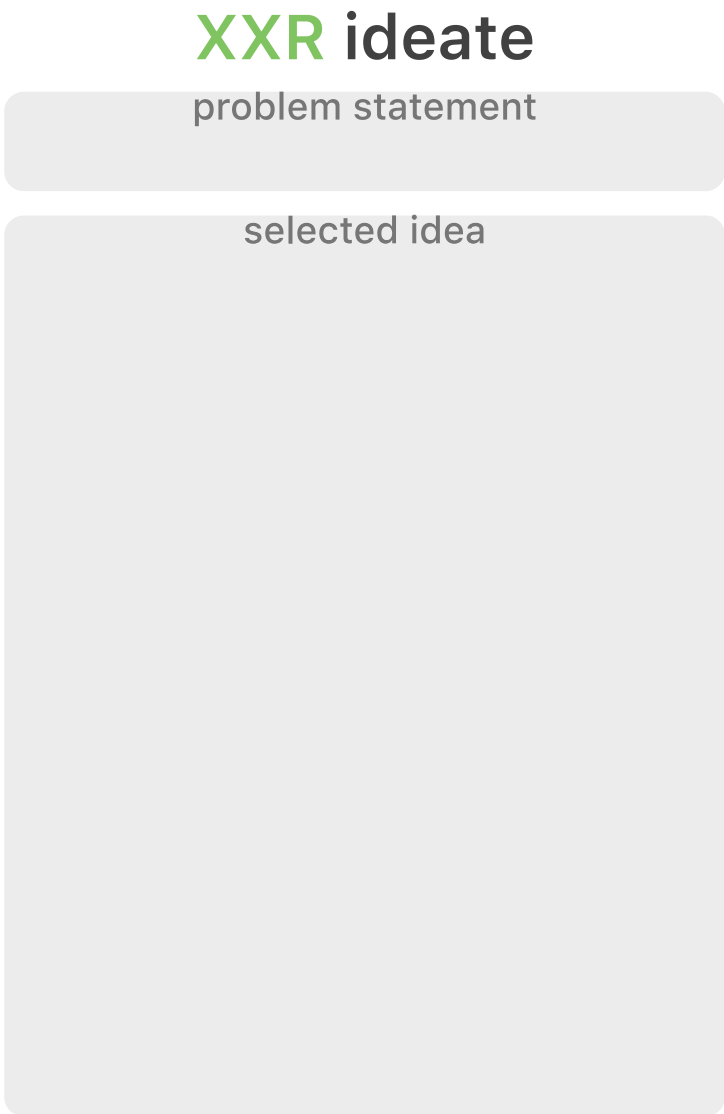
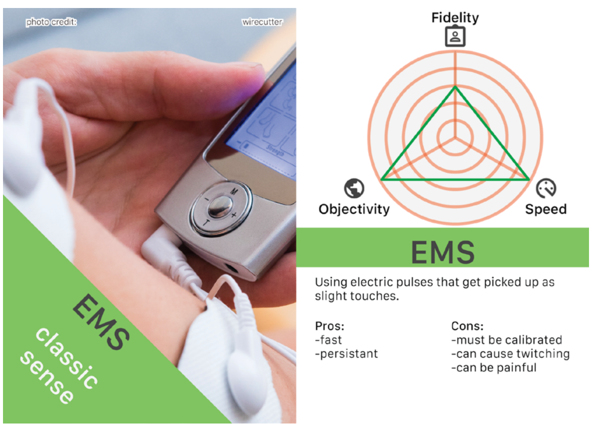


Figure 20.1: an example of the cards for each sense provided to the designers.



Modify

Description

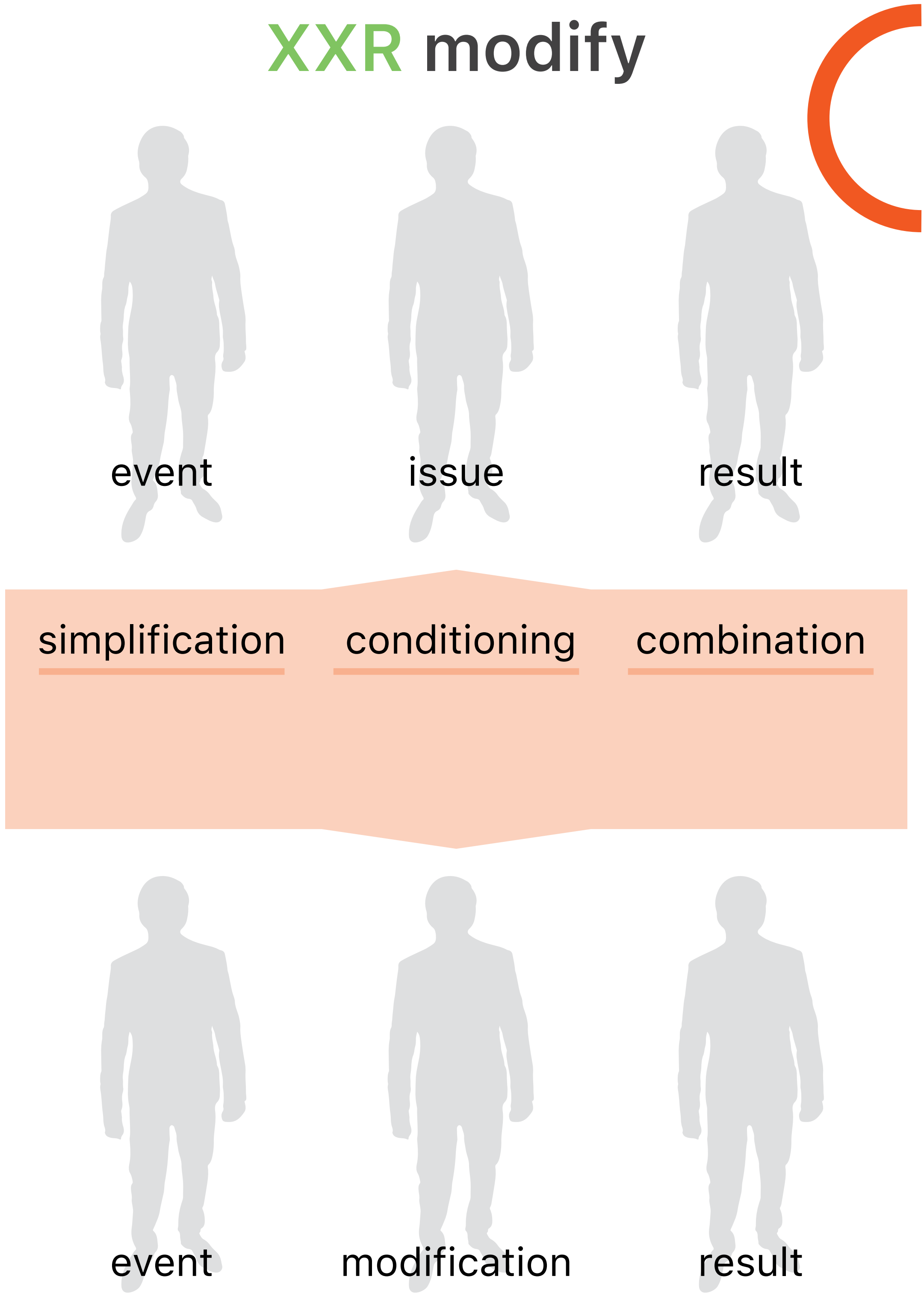
The modify step is an optional step that allows the designers to brainstorm changes to the approach or even additional techniques that help the selected sense(s) meet with the situation or criteria of the use case.

Goals

- Decide on what techniques are required to help increase the performance of the senses.
- Decide on how to implement them and what the desired improvement is.

Process

In the previous steps, designers should have discussed possible issues with using their selected sense, these issues should be storyboarded on the top of a sheet. Then the designers should use the suggested modifications as a jumping off point for Crazy 8's to generate applicable modifications. Then dot voting on these ideas in order to select which have the most merits. These modifications should then be story boarded on the bottom of the sheet.



Synthesize

Description

The synthesize stage is about looping the results of the tool back into the larger project in a presentable way. While the level of the results will differ in projects, some will end with a sense and some possible interactions and others with concepts, the sense and some interactions should be clear at the least.

Goals

- Document the Problem Statement, Selected Senses, and any Modifications.
- Visualize and or role play the modified or additional interactions that use the sense.
- Determine what assumptions are being made and need to be tested while prototyping the larger product.

Process

The designers restate the Problem Statement, the Selected Senses, and any Modifications. Then sketch out where the sense is actuated on the user and in context. Then it is highly suggested to work out a roleplay for each of the interactions that allows the team (and anyone who is shown this) to better understand the interactions.It is highly suggested to record this for archival and sharing purposes. Alternatively, the designers could storyboard these interactions, or do both.

XXR synthesize

We're going to problem statement______
by sense(s)______
with the addition of modification______

30 Use Case

"Constant attention by a good nurse may be just as important as a major operation by a surgeon." - Dag Hammarskjold

Introduction

In order to validate the tool it is important to develop a use case were extra senses: are helpful reducing the overload on sight and sound, has a large impact, and can truly improve the experience. These goals, plus the experience and contacts of mentor Elif Ozcan Vieira pointed towards Nurses as a very interesting target user. Additional analysis and interviews with nurses at EMC in Rotterdam, the Netherlands resulted in the idea of focusing on nurses in the ICU and nurses in training. Finally, these two groups are discussed and the specific case for each is described.

Why Nurses?

Alarms in hospitals are numerous and can easily lead to "alarm fatigue" which causes nurses to not notice loud noises which extra sensory input can cut through. The value for nurses to get more accurate information is also very high, a better situational understanding leads to better care for the patients which can help save lives and improve recovery.

Finally, the nurses and by extension the patients they help treat are often in urgent and critical situations, thus every second saved and every percent more accurate the nurse's understanding of the situation has a deep impact on the life and recovery of the patients.

Nurses are an interesting and important use case for extra sensory design. In order to better focus the tool, two specific cases were selected: helping nurses see in the dark and helping nurses in training understand how urgent alarms are.

Figure 30.1: the hallway of the ICU care rooms at Erasmus Medical Center (credit: Critical Alarms Lab)

Helping Nurses See in the Dark

Patients often stay in the ICU for several days, thus is is important for them to be able to sleep. This is challenging due to their condition and the stressful environment of the hospital room. Hospitals work to ensure that things are kept as quiet and dark as possible. However, this makes activities for the nurse, such as checking in on the patient or responding to minor alarms, much more challenging.

Because of the heightened importance for the patients and the restrictions on the traditional senses, this situation is selected to be the first of the two use cases to test the tool with.

Helping Nurses in Training Feel Urgency

When nursing students are starting out it takes a significant amount of time to develop an understanding of how urgent alarms are. This takes a long time as the alarms all sound very alarming. Additionally situations like a patient being moved and triggering a lot of alarms are common, but can cause new nurses to panic.

As VR training for nurses becomes increasingly common, nursing students are taught how to respond to certain situations and are drilled on proper procedures in simulations. This presents a very interesting opportunity: use these VR training simulations with additional senses to help nurses in training develop a "feeling" for the urgency of different alarms.

Figure 30.2: the hectic environment of the ICU at Erasmus Medical Center (day).

Figure 30.3: a visualization of a person training to be a nurse in a VR simulation (credit: UbiSim)

41 Helping Nurses See in the Dark

“Stars, hide your fires; Let not light see my black and deep desires.” - William Shakespeare

Summary

The tool was tested with the task of "seeing alarms in the dark" was addressed by six designers at Mobgen | Accenture Interactive. During this process, it was noted that the criticality and speed required meant that the sensations were off the table.

Designers thought that the tool could benefit from allowing the designers to do work separately and then discuss at each step. The resulting concept from this was a bracelet that used vibration to help nurses feel if they are pointed at the correct alarm.

Set up

In order to quickly disseminate information to the designers, three posters that show the process of handling alarms in the dark, the context of the ICU, and finally the nurses station. Then the reseach gathered during interviews conducted at EMC was explained as well as some of the observations.

Following this, the designers were given instructions on how to start each step and then allowed to discuss and complete each step. Some intervention was done to help end a stage in a definitive manor.

Feedback on Tool

Once the session had concluded, the designers were asked to provide feedback about the process and tool. This feedback, in combination with observations during the session, resulted in three major changes in the tool:

- The removal of the "Classification" phase.
- The shift towards a more structured and individual workshop format.
- The addition of a "Ideation" phase.

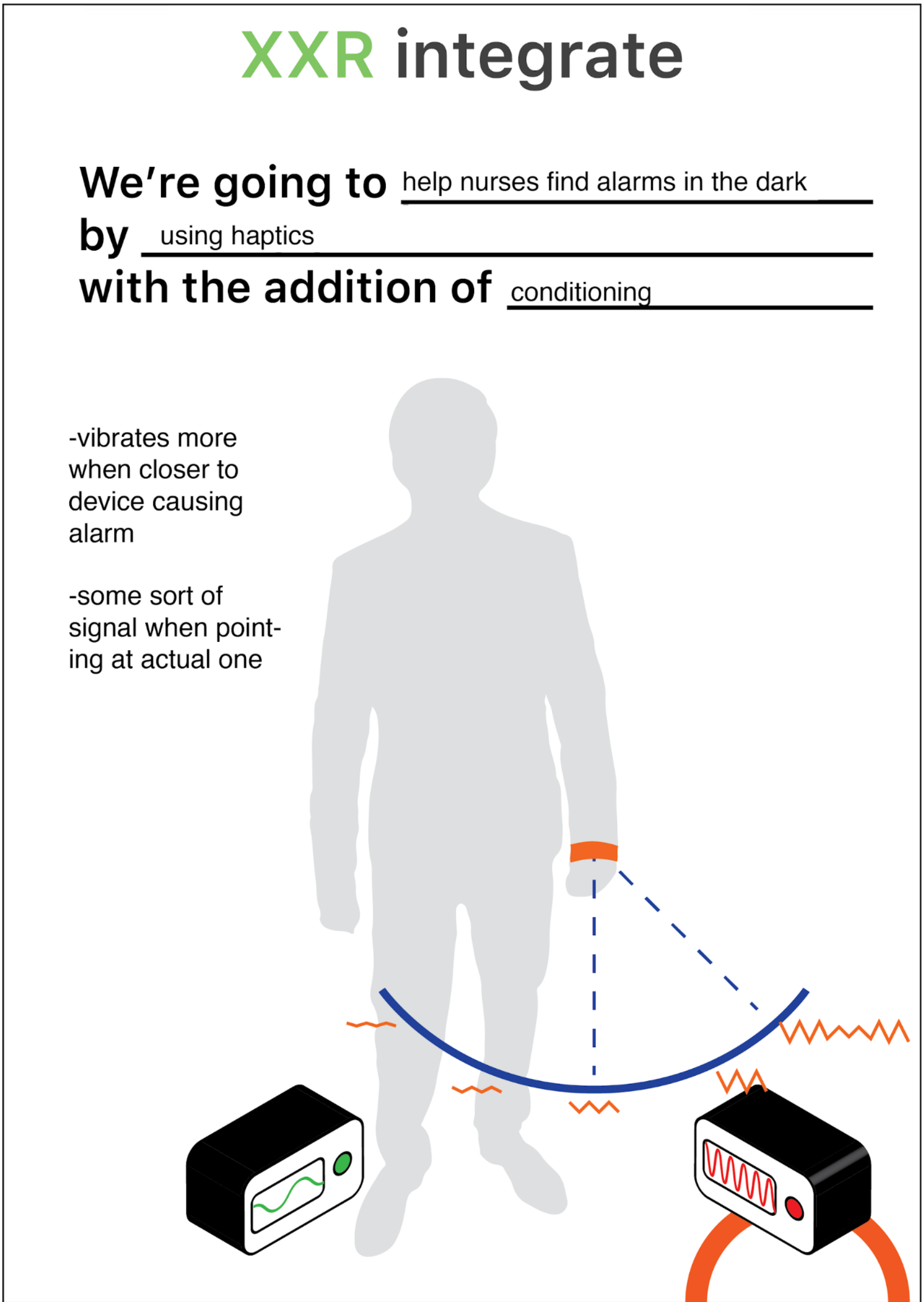
Figure 41.1: The posters that provided context to the designers on the left and the posters of the design process on the right.

Figure 41.2: despite being well received, the rate step caused a lot of hesitation during dot voting because it was not clear whether the designers should vote all at once or in which order.

Resulting Concept

The resulting idea was simple: create a wrist mounted device that would help the nurse 'feel' which alarm was most important by vibrating when the nurse points at the equipment that is causing the alarm. In order to help the nurse locate the alarm, the device not only confirms that the nurse has located the proper alarm with a confirmation pattern, but also tells the nurses if they are getting closer or further away from the equipment the nurse is.

Figure 41.3: a cleaned up version of the Integration stage.



42 Building a Sense of Urgency

“Identify the important and act with a sense of urgency.” - Anonymous

Summary

During the second test of the tool, the task of "helping nurses training in a VR simulation feel how urgent the situation is" was addressed by six designers at Mobgen | Accenture Interactive. During this process, it was noted that the criticality and speed required meant that the sensations were off the table.
The resulting concept was to use vibration and heat on the nurses' feet to help them feel the urgency in rhythm and temperature.

Set up

Designers were given the prompt to help convey the level of urgency of a situation in a VR nurse training simulator. This means that the nurse in training would be in a totally controlled situation and the severity of the situation known to the simulation. The question was how to impress the urgencyof the alarm with additional senses.

The designers were presented with a pair of videos describing the VR training environment as well as videos showing how the urgency of a situation did not fit smoothly with the attitude of the alarms in an ICU.

Feedback on Tool

Once the session had concluded, the designers were asked to provide feedback about the process and tool. This feedback, in combination with observations during the session, resulted in three major changes in the tool:

- The alteration of the categories in the Rank stage.
- The modification of the sense cards.
- The overhaul of the timing.

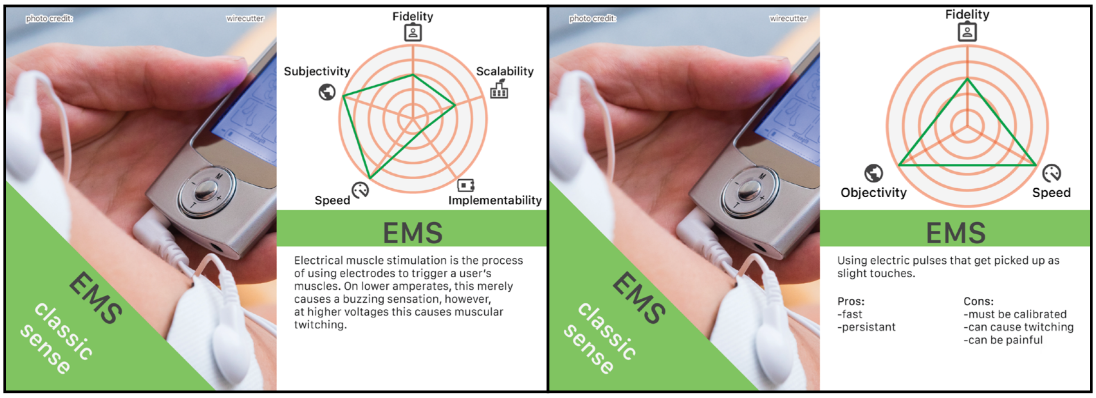


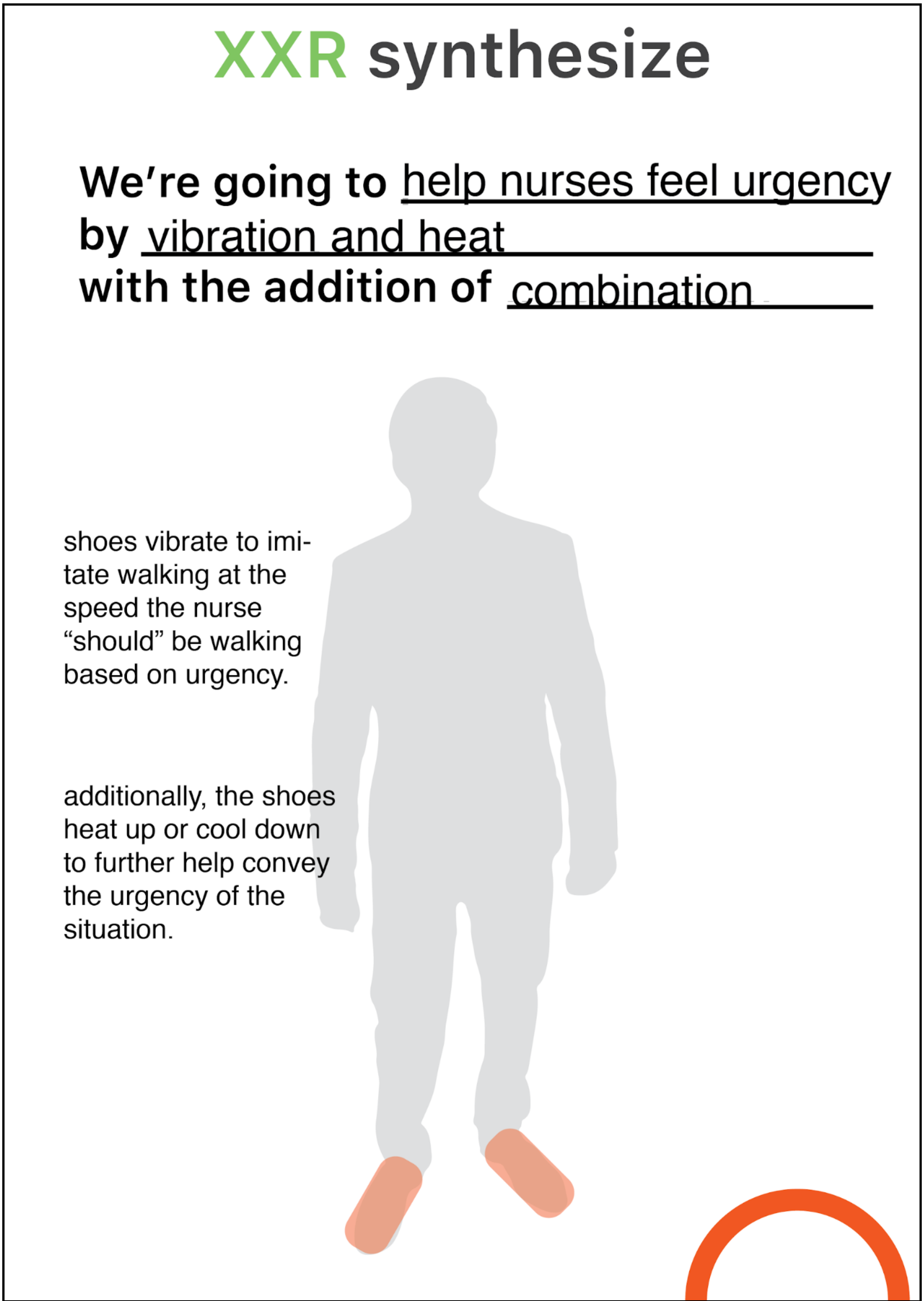
Figure 42.1: The old layout of the Sense Card for EMS (left) next to the updated layout (right).

Figure 42.2: Designers reviewing previous ideas before writing down new ones.

Concept

The resulting concept used vibration in a similar way to the concept from the previous section. The difference in this case is the vibration is target at the user's feet, so that the timing of footsteps can be mimicked in order to help the nurse in training feel the "tempo" of the situation. Additionally, while the designers were voting, there was a discussion of incorporating temperature in order to help induce more urgency.

Figure 42.3: a cleaned up version of the Synthesize stage.



50 Selecting a Solution

“We are what we pretend to be, so we must be careful about what we pretend to be.” - Kurt Vonnegut

Introduction

After having conducted the workshop twice, two interesting ideas came forward. However, for the sake of time and completeness, it was decided to only develop one of the two ideas into a full concept. While many different factors resulted in the final decision, the major one was the how close the demo comes to the eventual real life use case. Additional considerations were the number of senses used, the risk of eventual use, and finally the level at which the demo targets the users.

For the purposes of this section, the concepts generated in sections 41 and 42 are referred to by their section number.

Selection

Number of Senses

Concept 42 featured a true combination of two senses (vibration and heat) to translate the sense of urgency onto a nurse in training. Concept 41 meanwhile only uses vibration as an input to the user. This means that concept 42 can tell us more about how different senses build on each other and can create deeper experiences which cannot be done with concept 41.

Risk of Eventual Use

One of the main points of discussion after the generation of concept 41 was the fact that nurses would have to rely on this system in potentially life threatening situations. While truly dangerous situations would bypass the vibration indication, there are still plenty of potential missteps that could have disastrous implications for patients in an ICU. On the other hand, concept 42's targeting of nurses training in VR simulations completely removes the real life risk of sensory input being misinterpreted or ignored. Instead it functions as a guide future nurses can pay attention to and helps them develop better instincts for their future work.

Targeting: emotions not information

While concept 41 simply transfers the information of where an alarm is located in a room, concept 42 goes beyond this pure information transfer function and tries to transfer an emotional state. This makes the process of flushing out the concept and the impact of the demo much more interesting. Additionally, concept 42 does transfer some base information (whether or not the alarm is there), which means it covers a lot of the same ground as concept 41.

Demo-Real World Fit

The most important selection criteria was how well the demo could emulate the eventual real world application. This reflects the previously discussed fact that one of the concepts has to work in critical situations, while the other is a demo in VR space that would be used for VR space. More crucially the testing and results of a demo that is closer to it's eventual real world project is clearer and carries more meaning.

Adjustment

In order to make the development and testing of Concept 42 easier, some adjustments were made. Namely the two largest adjustment are the placement of the device and the switching from vibration to alternating pressure. A number of smaller adjustments or additional details were added to flush out the concept as discussed in section 60.

Placement of the Device

Concept 42 was originally envisioned to work on the user's feet and or ankles. Unfortunately this requires integration into shoes or socks, which in turn presents a plethora of hygienic issues. Additionally, developing a device that fits into the users shoes or socks but does not get damaged from regular use while remaining flexible enough to not interfere is a challenge in and of itself.

In order to avoid these issues, it was decided to move the demo to the user's upper arm, this way it stays free of major joints and forces. Furthermore the upper arm of the user is usually covered by a shirt, reducing the hygenic considerations of use.

From Vibration to Pressure

Based on interviews conduced at EMC, it quickly became apparent that nurses are already exposed to vibration as an input via their pager systems that alert them of alarms remotely. The possibility of miss-training a new nurse to interpret vibrations means that the demo needed to shift the sense slightly. By using a blood pressure cuff to give "vibrating" squeezes, the demo creates enough congnitive distance from vibrator motors.

60 The Demo

"What is it indeed that gives us the feeling of elegance in a solution, in a demonstration?" - Henri Poincare

Introduction

To recap: the demo will help convey a sense of urgency using both vibration and heat to nurses who are training in Virtual Reality. This chapter covers the development of that demo. In order to go from concept to demo, nurses were interviewed to help gather the levels of urgency as well as how these levels feel to them on a physical level. A VR environment of an ICU room was created to simulate a nurse's training simulator. Then hardware and software were built to connect the senses and the virtual environment.

Urgency Analogies

In order to better translate the idea of urgency through pressure and heat, a brief study was conducted with nurses at Erasmus EMC in Rotterdam, the Netherlands. The aim of the study was to an "embodiment" of three different levels of urgency. The embodiment is a description of the physical sensations nurses experience at certain moments, matched up with how urgent those moments are.

These analogies point to a clear path for helping people in VR experience the three different levels of urgency sensation. Using these different sensations, nurses who are training be able to understand the difference between the levels, they will also be able to "feel" or experience the urgency of a level based on the experiences of real life nurses.

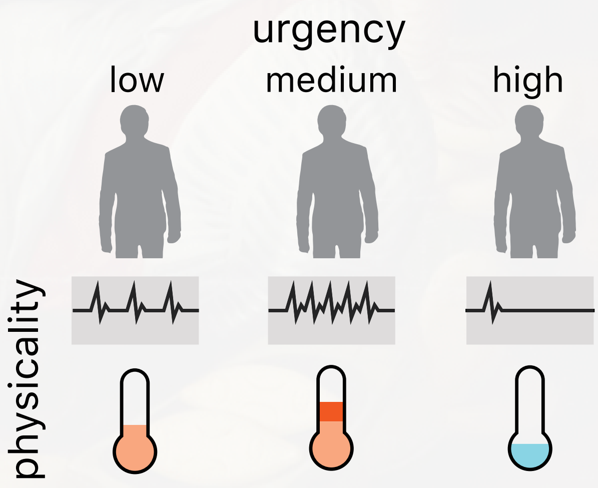


Figure 60.1: The three physicalizations (based on temperature and vibration) for ugrency shown graphically.

Technical Set-Up

Hardware

Using the Google Cardboard as the VR head mounted display, dramatically simplified the development process, at the cost of immersion and interaction possibilities. This tradeoff was necessary in order to fit into the scope and timeframe for this graduation.

Figure 60.2: A Google Cardboard VR viewer (Google)

Microcontroller and Actuators

The microcontroller used is an ESP-8266 based board. This handles both WiFi communication and controlling the actuators. Additional hardware was needed to ensure the system could tolerate current and voltage requirements: a power module and two H-bridge controllers. A schematic is shown in Figure 60.3. The power module takes a 5 volt USB input at provides the necessary 5 volt and 12 volt rails.

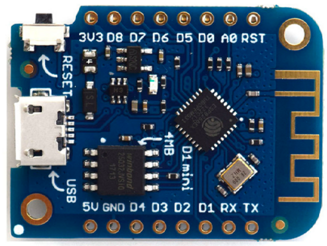


Figure 60.3: The original ESP8266 based microcontroller.

Actuators

Vibration comes from a modified blood pressure measuring cuff. A Peltier device both heats and cools the user, depending on how the voltage is applied.

The pressure cuff not only provides the pump and bladder, but is also a convenient embodiment and attaching mechanism for the entire demo device.

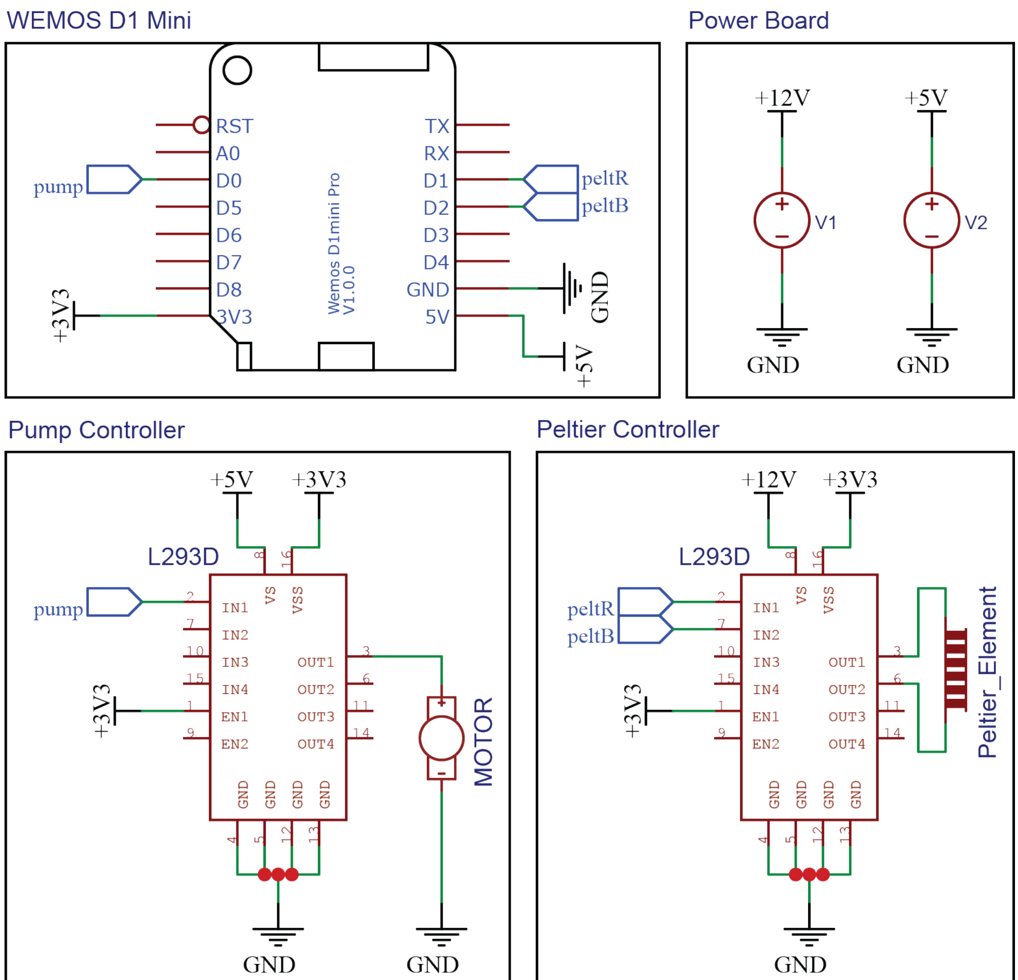


Figure 60.4: The schematic for the actuator electronics that power the demo device.

Software

A simple mock-up of the ICU was made in Unity 3D (as this was the software the author was most familiar with). Models for the environment were created based on photos of the ICU patient rooms at Erasmus MC in Rotterdam. This was kept bare bones and slightly abstract due to time contraints. The view of the user is shown in Figure 60.4

Bridging

In order to show how easy it is to integrate the solution into existing VR and AR projects, it was decided to not only integrate the demo into Unity 3D, but also give the possibilities to add the demo into any number of programs using OSC. Open Sound Control (OSC) is a commonly used protocol for addressing sound equipment and it's adoption by the Arduino community makes implementation a lot easier. Thus, the generalized software solution is shown in Figure 60.5

This allows for easy integration into a variety of software platforms ranging from professional VR installations to simple Android phones.

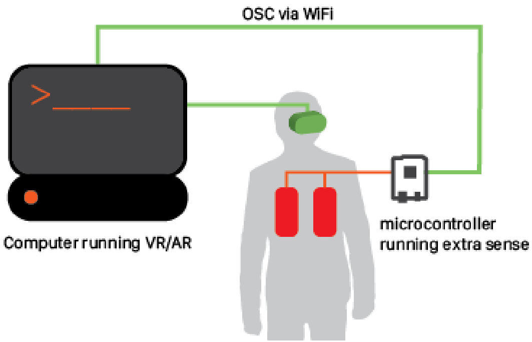


Figure 60.5: a simplification of the simulation and control system.

Microcontroller Code

The implementation of this is rather trivial, with the Unity software being responsible for most of the heavy lifting computationally. The microcontroller simply listens for OSC messages that tell it to actuate the senses. A call to the address "/cooler" tells the controller to turn off the device (case 0), cool the user (case 1), or heat the user (case 2). The address "/pressure" simply sets the motor to the given state (0 or 1). The full code can be found online at: github.com/womei/Demo42

Figure 60.5: The user's view of the VR enviroment.

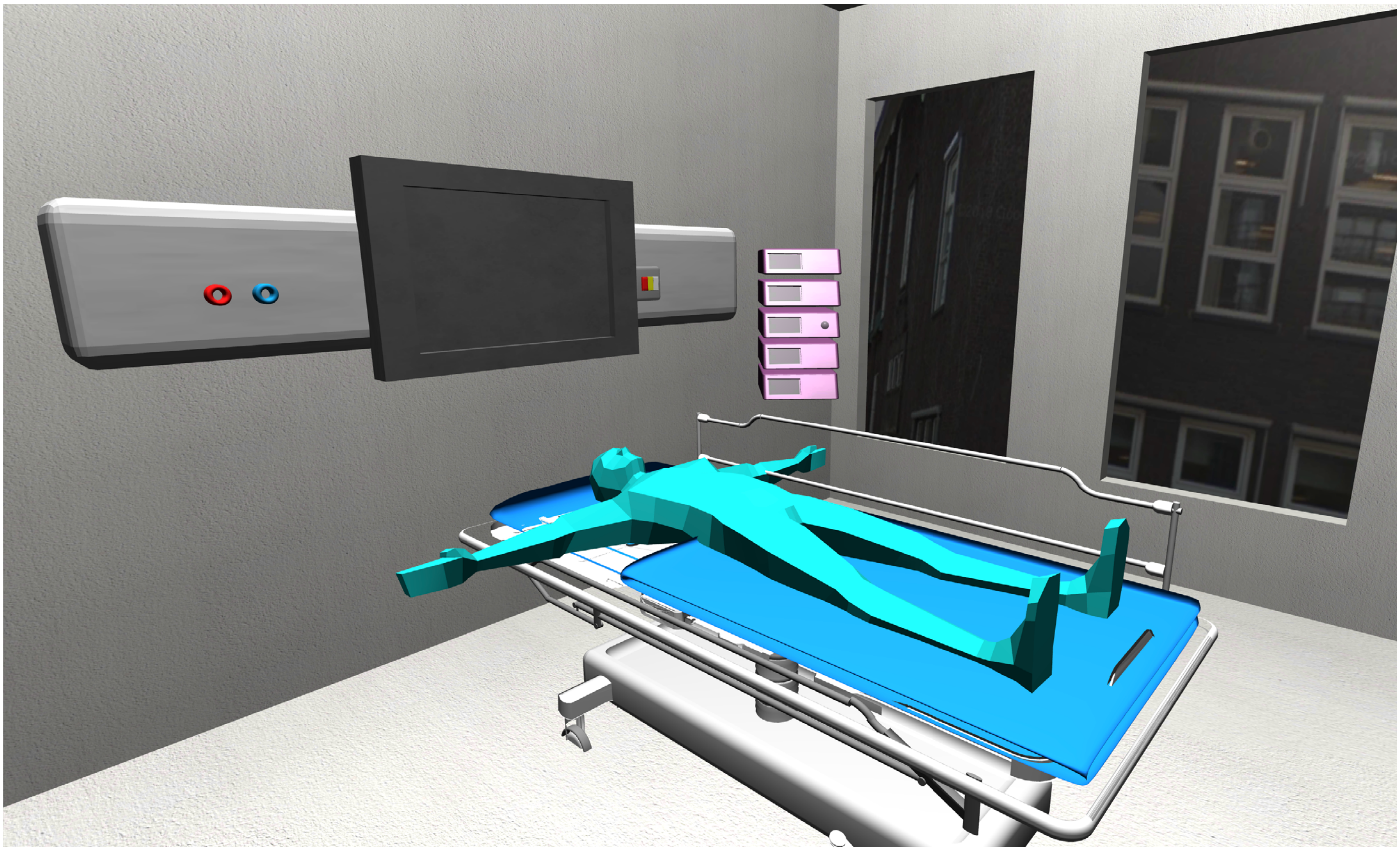
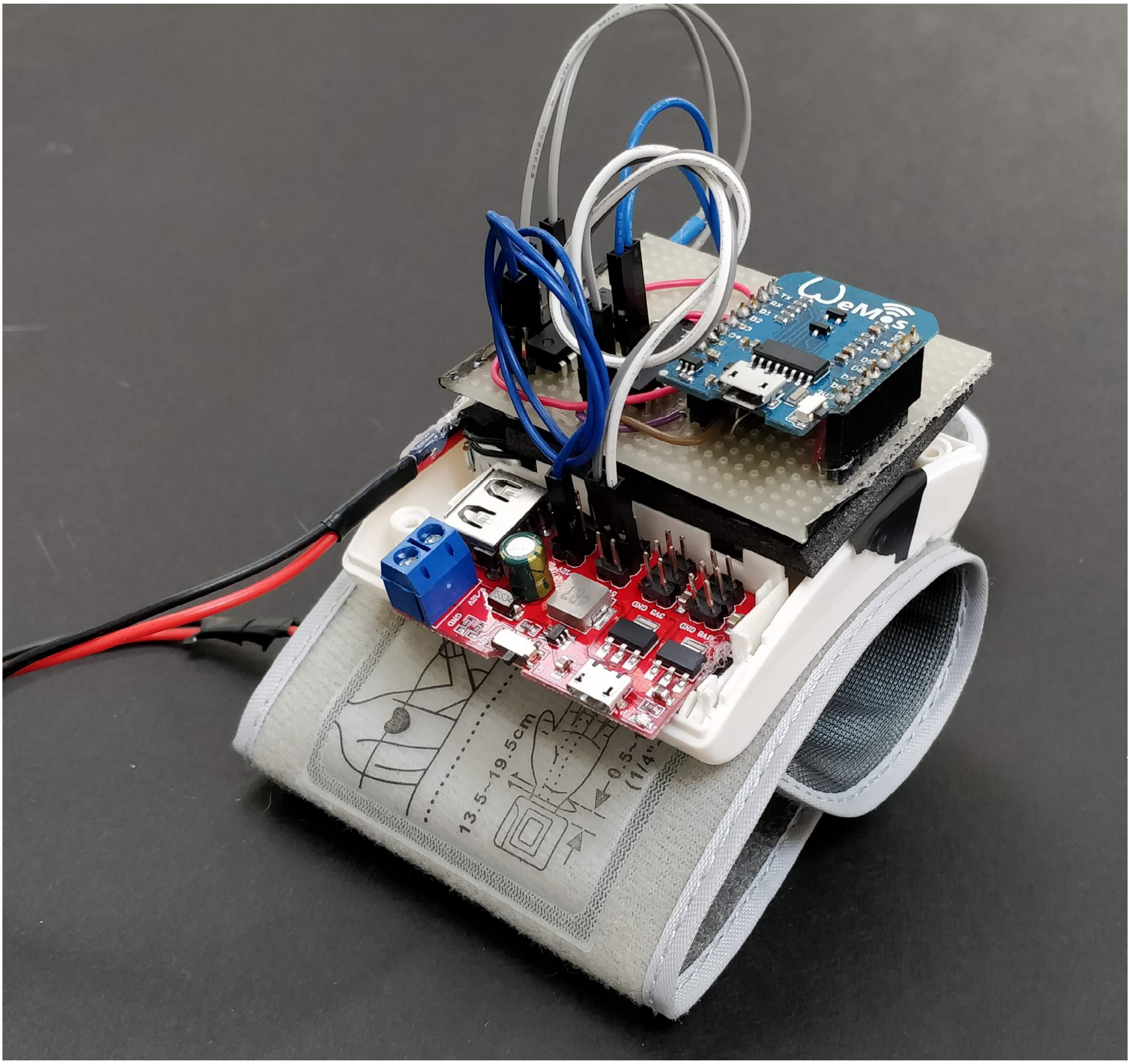


Figure 60.6: The final prototype of the Demonstrator used for testing during the graduation.



70 Testing the Demo

“Testing leads to failure, and failure leads to understanding.” -Burt Rutan

Introduction

Based on the use case for helping those becoming a nurse in VR training feel a the level of urgency a test was conducted using the demo discussed in Section 60. Not only does this test validate the demo, it also helps show that the underlying ideas and methods of the XXR Tool lead to more engaging and experiential VR applications. The test gathered both qualitative and quantitative data about testee's perception of urgency. It helped demonstrate that hotter temperatures did help show an increase in perceived urgency, however cold was often ignored or misinterpreted.

Procedure

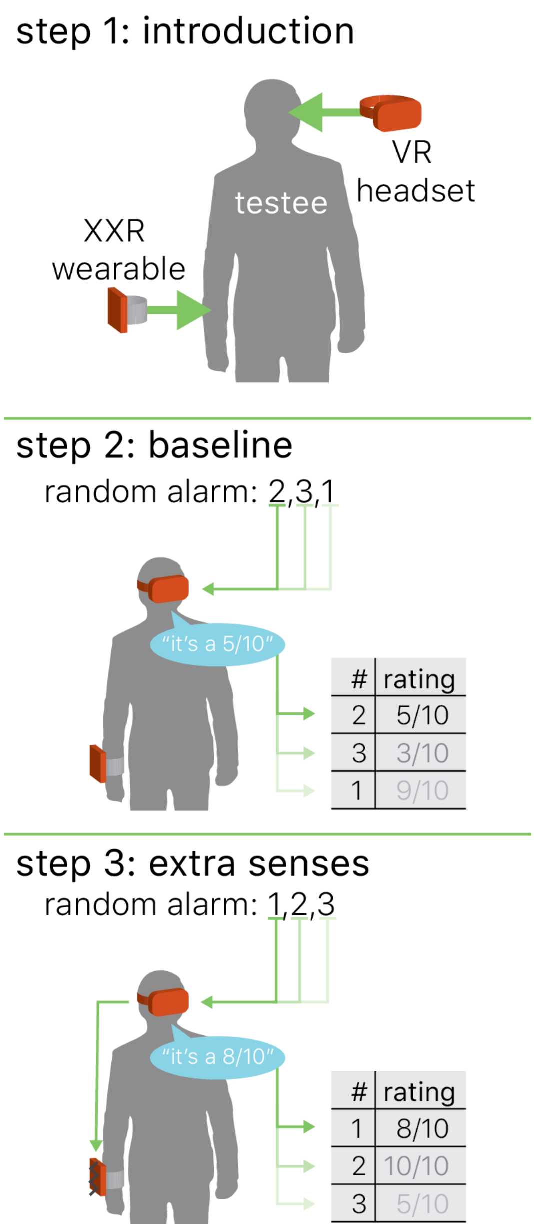
To begin with, the VR environment was enhanced to include three different alarms, all sourced from a Youtube video (McGrath, 2016) containing several ICU sounds, which were then associated with three different levels of urgency:

- Low (the sound of a medicine pump running low).
- Medium(low blood pressure warning).
- High (heart stop warning).

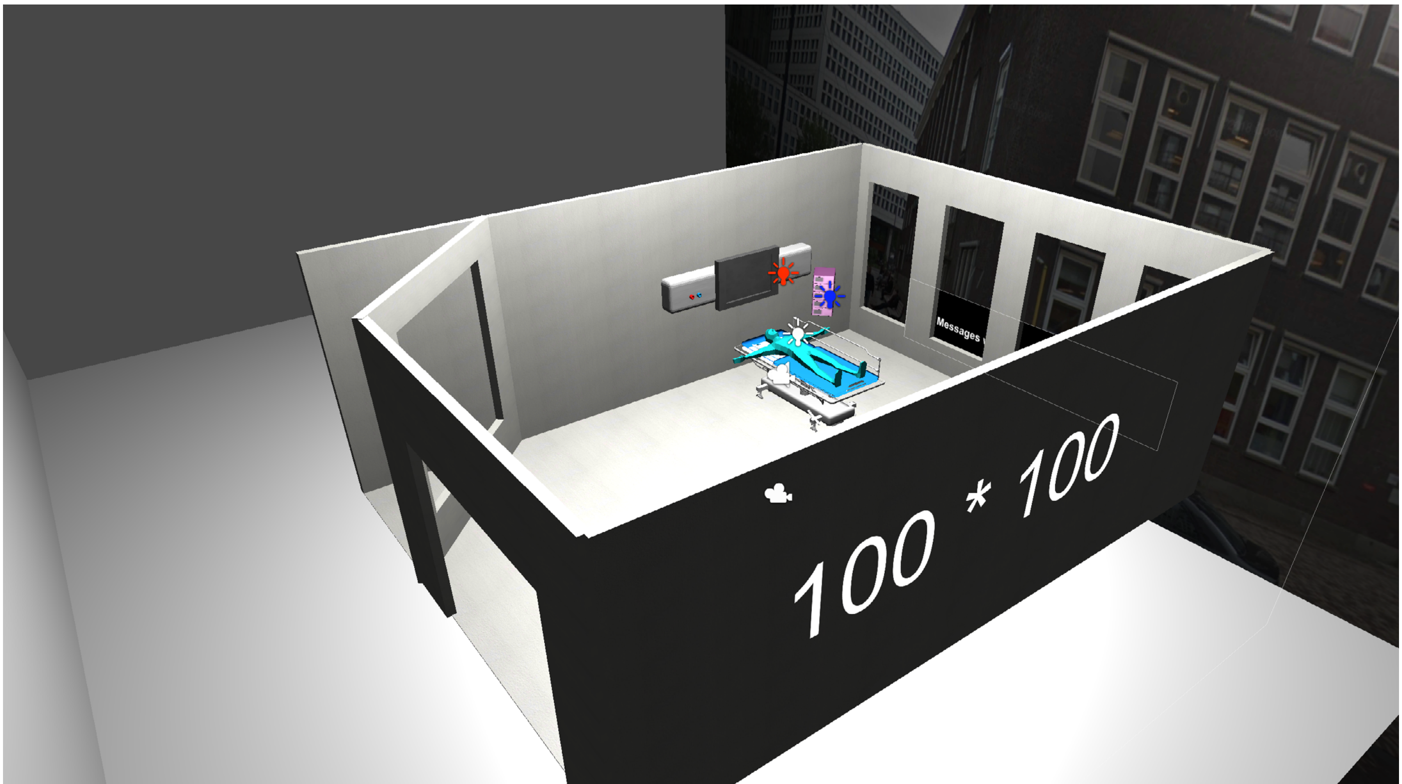
These three sounds were also given a simple light in the VR environment to help simulate the real world: a blue light on the medicine pumps for low urgency, a red light near the monitor for medium urgency, and a general light around the patient for high urgency.

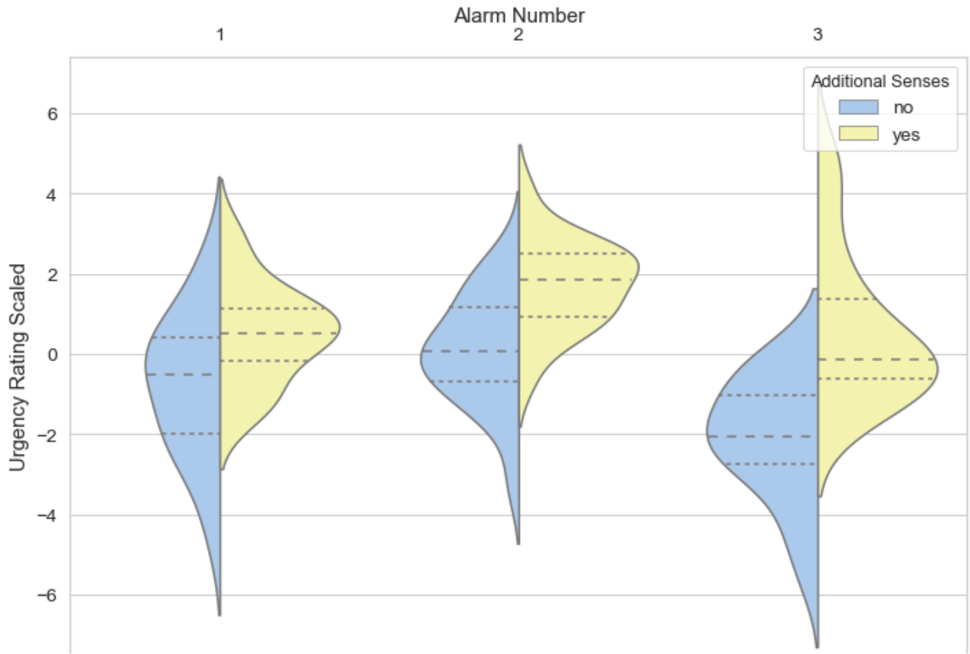
In addition to the alarms, simple math questions were shown on the wall away from the patient. This was done so that the testee would not constantly brace and wait for the alarm to come.

Figure 70.1: The flow chart of the testing procedure. A testee experiences the three alarms in random order, rating each one's percieved urgency. Then experiences the three alarms again in random order, with the wearable providing additional sensory input. Again the user rates their percieved urgency.



(below) Figure 70.2: an overview of the alarms and math questions in the VR environment.





(left) Figure 70.3: The paired distribution plots of scaled rated urgency of the three different alarms with and without additional senses.

Results

The test was conducted with sixteen people from a variety of backgrounds, with most being fellow students at the TU Delft between the ages of 20 and 30. Testees were almost an even seven women and nine men. A complete record of the results can be found in 904 Appendix 4.

Distributions

The first stage of the analysis is to look at how the distributions of scores for each urgency level changed between just the alarm sounds and light, and the alarm with the extra sensory input. First the average urgency rating for both sets of tests are subtracted from their respective ratings to remove variance in baseline rating.

Figure 70.3 shows the violin plots for the urgency ratings of the three alarm levels for just the light and sound (no additional senses, blue) and light, sound, and the additional sense of temperature and pressure (yellow).

Confusion Matrices

Confusion matrices offer an insight into the accuracy of the testee's perception. These show the level of urgency the alarm was intended to project, and the level classified by the user (as defined by being smaller than the median score for low urgency, the median for high urgency, and greater than the median for high urgency). Table 70.1 shows the confusion matrix for the alarms while Table 70.2 shows the confusion matrix for the alarms with additional senses.

	precision	recall
Alarms		
Alarm 1	0.33	0.33
Alarm 2	0.39	0.39
Alarm 3	0.00	0.00
Alarm + Sense		
Alarm 1	0.33	0.33
Alarm 2	0.22	0.22
Alarm 3	0.22	0.22

Table 70.3: precision and recall for all of the alarm and alarm and sense ratings given by the testees.

Table 70.1: the confusion matrix for just alarms.

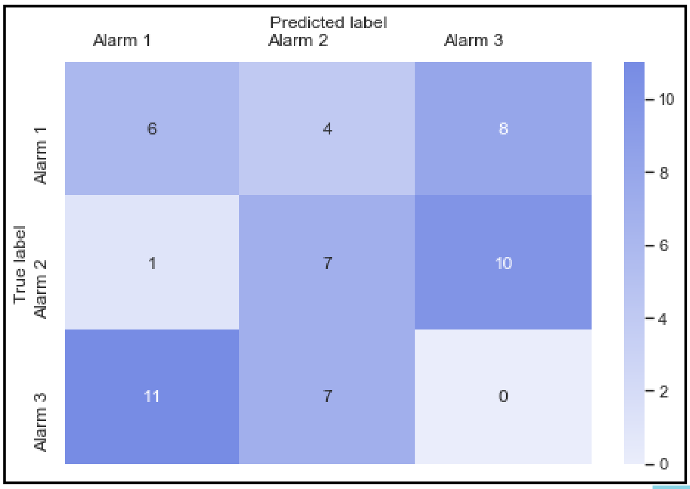
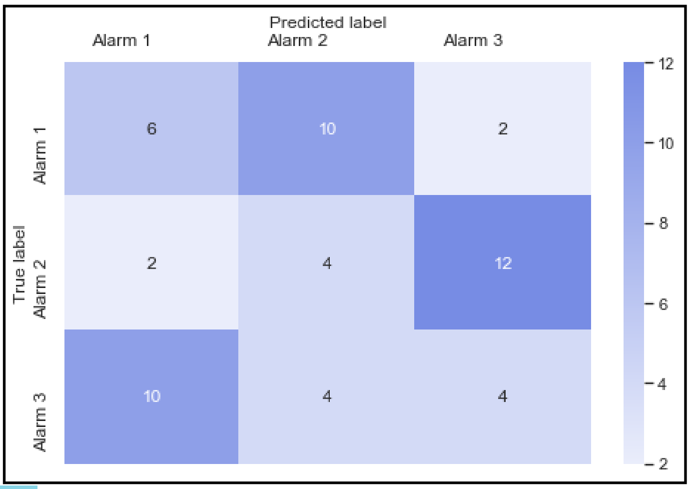


Table 70.2: the confusion matrix for alarms with additional senses.



(below) Figure 70.4: One of the testees explaining his discomfort.

Qualitative

The verbal feedback given during the tests varied wildly, in order to help show the qualities that were associated with the alarms a few quotes are provided for all of the alarm level and sensory combinations.

Alarm Level 1

"I feel like the equipment is broken"
"This sounds like a toaster"
"Oh, this is not important at all"

Alarm Level 2

"If I was a nurse seeing this I would be bored"
"This is more urgent! Someone is dying"

Alarm Level 3

"I think everything is okay, maybe the patient needs something?"
"This seems quite important, like the patient is going to die"

Alarm and Additional Senses Level 1

"Okay, now I should pay attention! This feels like it's really directed at me!"
"This really feels like I need to do something"
"This feels important, but it's missing the heat [from Alarm and Additional Sense Level 2] so it's less important"

Alarm and Additional Senses Level 2

"Oh, that's big"
"This is the most annoying thing, I have to do something"
"Something is going on, the heat makes me want to care for someone more"

Alarm and Additional Senses Level 3

"Oh no, this is horrible, and gross. I don't like this, why is it cold? Can you make it stop?"
"Is this supposed to happen? The chill in hands make it feel like something needs attention"
"I don't like this, I guess something is wrong, but it's more like I am in danger than my patient"

(left) Figure 70.5: One of the testees describing the effect of cold on his perception of the alarm.

Conclusions

Cold Does Not Work

Looking at the confusion matrix in Table 70.2, it can clearly be seen that the use of cold (for alarm and sense 3) does not impart the desired level of urgency. This means that the improvement for the additional senses is mainly in the first two levels, as discussed further in this section.

When looking at the qualitative results however, a few testees seemed to have very strong reactions to the cold. There are a number of reasons for why this could be (personal experience, sensitivity to cold, ambient temperature) necessitating a further study in order to truly understand how and when to use cold as a local temperature input for someone in VR.

Adding Senses Helps

Despite the apparent failure of cold as a sensory input, the effects of the additional senses for Alarm and Sense 1 and Alarm and Sense 2 is very apparent. Figure 70.6 shows the distribution of scaled urgency ratings for alarms 1 and 2 and alarm and senses 1 and 2. It is clear that the means of the ratings with the additional senses are further apart. In fact, running Student's T test (Table 70.4) proves that there is a statistical difference between the two alarms with senses, as opposed to the two alarms without (using an alpha = 0.05 significance value). This is further backed up by the qualitative data, which points to an understanding of the differences in rhythm as well as noticing the heat as an increase of urgency.

	t	p
Alarm 1 and Alarm 2	-1.56	0.1276
Alarm and Sense 1 and Alarm and Sense 2	-3.18	**0.0032**

Table 70.4: the T Test of the scaled urgency ratings between alarm 1 and 2 for alarms without and with additional senses. It shows that there is not a significant ($p < 0.05$) difference between the two alarms only sets, but there is a statistically significant difference between the two sets with additional senses.

Adding Senses Changes Immersion and Ownership

As can be seen in the qualitative data, the use of additional senses (especially with Alarm and Additional Senses Level 2) changes how people interpret the alarms. Several of the testees felt like the alarm with additional sense addressed them specifically, rather than just being a general alarm. This means that additional senses gives a massive opportunity for increase not only the accuracy of the level of urgency, but also can be used in multi user training to help people training to be nurses get a better idea about which alarms they should pay attention to and give them a much more direct feeling of ownership over the alarm.

This can be seen when testees shifted from talking about the alarms as happening in the room (for just the alarm tests) to the alarms happening to them. This means that there are many possibilities for increasing the nurse in training's immersion by making physical connections between the VR simulation and inputs to their senses.

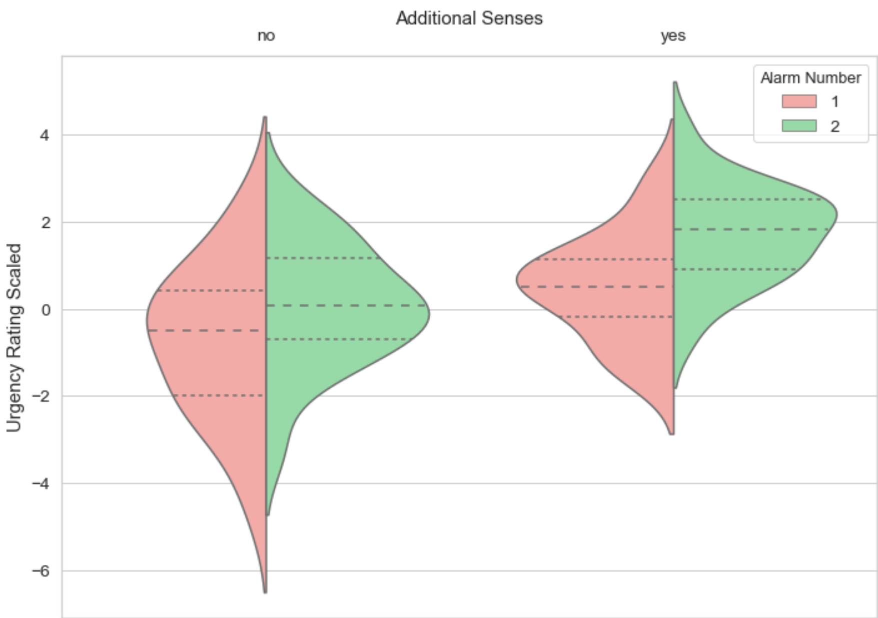


Figure 70.6: the distribution for the scaled urgency ratings of both alarm levels 1 and 2 with just the alarms on the left and the alarms and additional senses on the right.

Discussion

This test was essential in seeing how adding senses creates a difference in perceived urgency, that being said, there are a number of aspects that are ripe for future and more detailed study. Unfortunately, much like life, the time for the graduation was finite and the testing phase towards the end. This time constraint lead to limited realism in the VR simulation, limited interaction and metrics, and a small number of quick tests.

Limitations

One of the largest limitations of this study was the VR environment, which was made in order to quickly simulate the actual hospital room. This proved to be less than fully immersive, which influenced testee's engagement with and perception of the alarms. Additionally, the recorded background noise (meant to add to immersion and give more contrast to alarms) was too brief, which resulted in jarring splices when it looped.

The other large limitation was simply the number of small tests. Since each test had to be triggered and the responses recorded manually, the time a test took was much longer than expected. This, combined with overall time constraints resulted in a limited number of tests, of very small depth (simply having the testee rate their perceived urgency).

Future Research

Future research could easily expand on three elements of this study:

1. The use of VR for automated and highly tracked testing and data collection.
2. The emotional response to additional sensory inputs.
3. How people from different backgrounds perceive certain sensations.

VR for Automated Testing and Data Collection

As described in Limitations, an idea for the study was to use the nature of the VR simulation to be able to automatically guide the user through the testing procedure as well as pull a massive amount of information from their actions. This points to a new method of testing user that would allow designers to very easily collect a massive amount of data without increasing the workload of the user. However, additional research needs to be conducted into the feasibility of creating these VR environments, how the VR environment affects the user's perception and behavior compared with testing in real life, and which conclusions can be drawn from the data. The use of VR in design research could be the next evolution of techniques such as eye tracking and would allow for accurate timing and task analysis.

Emotional Response to Additional Sensory Inputs

This study just scratches the surface of how users' perception and emotional experience is changed when subjected to additional sensory inputs. Expanding this study or conducting similar ones will help the understanding of how humans process senses and use inputs to create an emotional understanding of their situation. This is also necessary for the efficient and impactful integration of other senses into extended extended reality project in the future.

How People From Different Backgrounds Perceive Certain Sensations

One of the observations from the study was how differently people reacted to the sensation of cold. Many testees simply ignored it, or did not find it important, whereas other testees had a very visceral reaction to it. The dataset is much too small to make any conclusions, however, the testees from countries with a warmer climate had the more visceral reactions. This points to some kind of learned or developed changed in perception of different sensations. A study that dives into this would be massively important to designers trying to target certain users using additional senses and would help further understanding of how nurture affects sensory perception.

80 Closing Remarks

“Beyond the fiction of reality, there is the reality of the fiction.” -Slavoj Žižek

Introduction

The section is for some final thoughts and observations. Readers interested in process or concrete discoveries have strayed too far from the previous sections.

Wearables as Extended Reality

One of the more controversial ideas discovered during this graduation is the idea of wearables as Extended Reality devices. The definition of what extended reality is is highly subjective but in the mind of the author, wearables can be used to extend the sensory space of the user. An example of this would be using a pressure cuff that extends the "pressure domain" observed by the user.

The Bennal Evil of Safe Choices

One of the most disheartening discoveries uncovered up to this is the innate tendency to drive towards a working result, which means that more experiential senses are often left behind. This is logical in the current technological context, however if the technological considerations could be left behind, much more interesting concepts could be created using the XXR tool.

Thus, in order to create more interesting concepts that help drive a future filled with solid design once the technology to power them becomes mature enough, a different take on the tool will be needed in the future. This take focuses on empowering designers to explore the different possibilities of having more control over a user's senses. A tool like this would be much more conceptual and difficult to define, and its nature inherently runs out of the scope of this graduation, especially at the late stage it was imagined in.

Satisfaction and Personal Growth

This graduation was not a simple, clear, or particularly straightforward process. The first major breakthrough was the realization that no one's graduation is. The second was how to know those two facts and still be satisfied with the process.

This is one of the many areas in which I am proud of myself for the beautiful mess that is this graduation. And the fact I am bragging about it on one of the final pages is another.

Figure 80.1: look at that happy face.

Sources

Aristotle. (350 BCE). De Anima. MIT. Retrieved from http://classics.mit.edu/Aristotle/soul.html

Barbaras, R. (2002). Francisco Varela: A new idea of perception and life. Phenomenology and the Cognitive Sciences, 1, 127–132. http://doi.org/10.1023/A:1020332523809

Bergmann Tiest WM, Kosters ND, Kappers AM, Daanen HA (2012). Haptic perception of wetness. Acta Psychol (Amst) 141: 159 –163.

Bronstein, A., & Pavlou, M. (2013). Balance. Handbook of Clinical Neurology, 110, 189-208.
Chartrand, T. L., & Bargh, J. A. (1999). The Chameleon Effect: The Perception-Behavior Link and Social Interaction. Journal of Personality and Social Psychology, 76(6), 893-910.

Cialdini, R. B., & Goldstein, N. J. (2004). Social Influence: Compliance and Conformity. Annual Review of Psychology, 55(1), 591–621. http://doi.org/10.1146/annurev.psych.55.090902.142015

Coren, S., & Girgus, J. S. (1978). Seeing is deceiving: The psychology of visual illusions. Oxford, England: Lawrence Erlbaum.

Filingeri, D., Fournet, D., Hodder, S., & Havenith, G. (2014). Why wet feels wet? A neurophysiological model of human cutaneous wetness sensitivity. Journal of Neurophysiology, 112(6), 1457–1469. http://doi.org/10.1152/jn.00120.2014

Freeman, E., Anderson, R., Williamson, J., Wilson, G., & Brewster, S. A. (2017). Textured surfaces for ultrasound haptic displays. Proceedings of the 19th ACM International Conference on Multimodal Interaction - ICMI 2017, 9781450355438(November), 491–492. http://doi.org/10.1145/3136755.3143020

Gigerenzer, G. (1991). How to Make Cognitive Illusiona Dissapear: Beyone "Heuristics and Biases." In W. Stroebe & M. Hewstone (Eds.), European Review of Social Psychology, Volume 2. Salzbury, Austria: John Wiley & Sons, Incorporated.

Guinan, A. L., Hornbaker, N. C., Montandon, M. N., Doxon, A. J., & Provancher, W. R. (2013). Back-to-back skin stretch feedback for communicating five degree-of-freedom direction cues. 2013 World Haptics Conference, WHC 2013, 13–18. http://doi.org/10.1109/WHC.2013.6548377

K. Shimada, K. Hiroi, N. Kawaguchi and K. Kaji, "Measurement methods of spatial ability using a virtual reality system," 2016 Ninth International Conference on Mobile Computing and Ubiquitous Networking (ICMU), Kaiserslautern, 2016, pp. 1-6. http://doi.org/10.1109/ICMU.2016.7742095

Kahneman, D., Knetsch, J. L., & Thaler, R. H. (1991). Anomalies: The Endowment Effect, Loss Aversion, and Status Quo Bias. Journal of Economic Perspectives, 5(1), 193–206. http://doi.org/10.1257/jep.5.1.193

Klatzky, R. L. (1998). Allocentric and Egocentric Spatial Representations: Definitions, Distinctions, and Interconnections. In C. Freksa, C. Habel, & K. F. Wender (Eds.), Spatial Cognition: An Interdisciplinary Approach to Representing and Processing Spatial Knowledge (pp. 1–17). Berlin, Heidelberg: Springer Berlin Heidelberg. http://doi.org/10.1007/3-540-69342-4_1

Lategan, L. (2011). Electrical muscle stimulation: Past, present and future: 3084. Medicine & Science in Sports & Exercise, 43(Suppl 1), 887-887. doi:10.1249/01.MSS.0000402476.40139.46

Lawson, R. (2013). Anatomy and Physiology of Animals. Anatomy and Physiology of Animals. http://doi.org/10.1017/CBO9781107415324.004

McDonald, J. J., & Ward, L. M. (2000). Involuntary Listening Aids Seeing: Evidence From Human Electrophysiology. Psychological Science, 11(2), 167–171. https://doi.org/10.1111/1467-9280.00233

Murakoshi, S., & Kawai, M. (2000). Use of knowledge and heuristics for wayfinding in an artificial environment. Environment and Behavior, 32(6), 756-774.

Owens, T. J. (2006). Self and Identity. In J. Delamater (Ed.), Handbook of Social Psychology (pp. 205–232). Boston, MA: Springer US. http://doi.org/10.1007/0-387-36921-X_9

Proctor, R. W., & Proctor, J. D. (2012). Chapter 3 Sensation and Perception Methods for Investigating. In G. Salvendy (Ed.), Handbook of Human Factors and Ergonomics (4th ed., pp. 59–94). John Wiley & Sons, Incorporated.

Purves, D. (2012), "The somatic sensory system," in Neuroscience, D. Purves, A. George, F. David, K. Lawrence, L. Anthony-Samuel, M. James, and M. Williams, Eds. Sinauer Associates.

Quek, Z. F., Schorr, S. B., Nisky, I., Provancher, W. R., & Okamura, A. M. (2014). Sensory substitution using 3-degree-of-freedom tangential and normal skin deformation feedback. IEEE Haptics Symposium, HAPTICS, 27–33. http://doi.org/10.1109/HAPTICS.2014.6775429

Salt, A. N., & Kaltenbach, J. A. (2011). Infrasound From Wind Turbines Could Affect Humans. Bulletin of Science, Technology & Society, 31(4), 296–302. https://doi.org/10.1177/0270467611412555

Sanchez-Vives, M. V, & Slater, M. (2005). From presence to consciousness through virtual reality. Nature Reviews Neuroscience, 6, 332. Retrieved from https://doi.org/10.1038/nrn1651

Stevens, S. (1963). Handbook of experimental psychology (Wiley publications in psychology). New Delhi: Wiley.

Thaler, R. H., & Sunstein, C. R. (2009). Nudge: Improving Decisions about Health, Wealth, and Happiness. Penguin Books.

Tversky, A., & Kahneman, D. (1974). Judgment under Uncertainty: Heuristics and Biases. Science, 185(4157), 1124-1131. Retrieved from http://www.jstor.org/stable/1738360

Unknown. (1936). The Senses. The Lancet, 287–288.

Wearden J., & McShane, B. (1988). Interval production as an analogue of the peak procedure: Evidence for similarity of human and animal timing processes. The Quarterly Journal of Experimental Psychology Section B, 40(4b), 363–375. https://doi.org/10.1080/14640748808402330

Wearden, J. (2016). The psychology of time perception. London: Palgrave Macmillan. doi:10.1057/978-1-137-40883-9

Weber, A. I., Saal, H. P., Lieber, J. D., Cheng, J.-W., Manfredi, L. R., Dammann, J. F., & Bensmaia, S. J. (2013). Spatial and temporal codes mediate the tactile perception of natural textures. Proceedings of the National Academy of Sciences, 110(42), 17107 LP-17112. http://doi.org/10.1073/pnas.1305509110

Ye, D. (n.d.). Adding laughter to increase presence in Virtual Reality, 1–7. Retrieved from http://referaat.cs.utwente.nl/conference/27/paper/7657/adding-laughter-to-increase-presence-in-virtual-reality.pdf

The XXR Tool

this was a successful graduation

```
#include <Arduino.h>

//Thanks so much to Stahl Now for the OSC code and examples
//https://github.com/stahlnow/OSCLib-for-ESP8266
#include <ESP8266WiFi.h>
#include <WiFiUdp.h>
#include <OSCMessage.h>
#include <OSCBundle.h>
#include <OSCData.h>

IPAddress local_IP(192, 168, 1, 100);
IPAddress gateway(192, 168, 4, 9);
IPAd
// A UDP instance to let us send and receive packets over UDP
WiFiUDP Udp;

const unsigned int localPort = 5005; // local port to listen for UDP packets (here's wh

OSCErrorCode error;

//Information for actuator wiring
const int PeltRed = D1;
const int PeltBlack = D2;
const int Pump = D8;

const int PeltMaxHot = 755;

bool LEDBlink = false;

void setup()
{
  // Set up all the pins
  // initite the motors and set to low:
  pinMode(PeltRed, OUTPUT);
  pinMode(PeltBlack, OUTPUT);
  pinMode(Pump, OUTPUT);
  pinMode(LED_BUILTIN, OUTPUT);

  digitalWrite(PeltRed, LOW);
  digitalWrite(PeltBlack, LOW);
  digitalWrite(Pump, LOW);
  digitalWrite(LED_BUILTIN, HIGH);
  // done setting up all of the pins

  //set up the WiFi network
  Serial.begin(115200);
  Serial.println();
  Serial.println();

  Serial.print("Setting soft-AP configuration ... ");
  Serial.println(WiFi.softAPConfig(local_IP, gateway, subnet) ? "Ready" : "Failed!");

  Serial.print("Setting soft-AP ... ");
  Serial.println(WiFi.softAP("Wo's thesis") ? "Ready" : "Failed!");
```