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USABILITY EVALUATION OF AV SYSTEM VIDEO MATRIX USER INTERFACES BASED ON DRAG & DROP PARADIGM

Faculty of Information Technology and Communication Sciences (ITC)
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Abstract

Lauri Heikkilä: Usability evaluation of AV system video matrix user interfaces based on drag & drop paradigm
Master of Science Thesis
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Several different interaction patterns can be utilised to control a video matrix with an AV control system. Video matrix is a component in AV system responsible of routing video signals from video inputs to outputs.

This Master's thesis focuses on evaluating usability of three video matrix user interfaces based on drag & drop paradigm over floor plan. These particular interfaces have been designed and implemented by the author and they have been in production use for some time. The usability of the interfaces were evaluated by the actual users of the systems using a questionnaire. Also, a heuristic evaluation and a brief expert review were performed to gain formative insights about how to improve the interfaces in the future.

The results were that the actual users of the systems were highly satisfied to the interfaces and the AV systems in general. However, heuristic evaluation and expert reviews pointed out that there are several feasible improvements that would make the usability better. The main issues were related to consistency, system state visibility and accessibility. Also, suggestions to smaller fixes and interaction paradigm enhancements were made.

The results and general insights were discussed so that AV system designers can utilise the gained information on decisions about which interaction pattern to choose for their systems. Also, it was noted that it is important to have a clear, validated and detailed conception about the actual context of use when evaluating the usability of a system - and preferably, when designing a system.

Keywords: usability, usability evaluation, heuristic evaluation, expert review, AV system, AV control system

Contents

1 Introduction

1.1 Motivation

If you've ever had a presentation in a meeting room or a lecture in auditorium, you might have noticed that the AV equipment (projector, screen etc) is controlled by some kind of a user interface. You could consider *user interface* broadly here - at simplest it could be just a remote control commanding a single projector or TV screen.

Even with a setup this simple you might run into problems: which input should I select? Which input is currently selected? Why there is no audio? Is it muted or do I have selected a wrong audio output on a laptop? Quite a few possible glitches in a situation where people is expecting to listen what you are going to say - not to watch you stressing out about technical problems.

When you add more components (microphones, video inputs, screen sharing devices, displays, projectors, etc.) to the AV system, the more potential hassle there will be due to added complexity. End users of AV systems typically get paid from other things than mastering complex AV systems, and therefore are not very motivated about spending their time studying the nuances of the systems.

Luckily users do not have to depend on remote controls for all of the devices. The more complex the AV system is, the more likely it is that it is commanded by a dedicated AV control system with an user interface, which aims to hide unnecessary features and tries to make the system as usable as possible.

This thesis focuses on AV control system user interfaces running on tablet - it is nowadays common that control user interfaces are run on tablets. To be more specific, a small section of the control user interface is discussed (and the rest is totally ignored): the part that controls the *video matrix*, a device that routes video feed from video inputs to video outputs.

There is not much of an existing research focusing specifically on AV system user interfaces (Myller 2011). However, general usability research and UI/UX design principles can be utilised. This thesis aims to create some connection between existing usability research and UI/UX design of AV control systems. It might also encourage readers operating in AV system design field to consider adding some methodological approach and considerations to their UX design toolboxes.

1.2 Brief introduction to AV systems

An *AV system* consists of audiovisual devices (projectors, TV displays, video input connectors, microphones, speakers, etc.) and some way (typically a cabling) that transfers audiovisual signals between devices.

A *video matrix* is a device in an AV system that routes video signals from video inputs to video outputs. Video matrix, as well as other devices, are controlled by an *AV control system*.

More comprehensive and detailed description of an AV system can be found at section 2.1.

1.3 Research goals

Goals of the thesis are

1. to **evaluate** the usability of three AV system user interfaces designed and implemented by the author - or more specifically, the part of the interfaces that control the video matrix,

2. to gain insights how to **improve** the usability of the particular interfaces (or interfaces created with the same pattern in the future), and

3. to **generalise** the results so that system designers can utilise the results when making decisions which interaction patterns are suitable for their AV system.

The interfaces evaluated are presented in section 3.1.

1.4 Interviews

As said, there seems to be none or little literature about usability aspects related to AV control systems specifically. Therefore, three interviews were conducted as part of the research to gain more insights about the subject. The idea was to gain professional views about interaction pattern possibilities and design strategies related to AV system usability in general. Interviewees were as follows:

- **Kantoniemi, Joonas**, Naava Visuals Oy
- **Mäenpää, Paiste**, AV-arkkitehti, Lyreco Finland Oy
- **Sivonen, Janne**, Technology team lead, Audico Systems Oy

Links to the full CVs of the interviewees can be found at the Interviews chapter, after the list of References.

1.5 Thesis structure

Content of the following chapters is divided as follows.

- Chapter 2 (Background) provides first an in-depth description about the relevant parts of an AV system. Then, it examines the possibilities of evaluating the usability of AV systems based on literature.
- Chapter 3 (Methodology) explains, justifies and describes the chosen actions and methods.
- Chapter 4 (Results) lists the results of research and provides improvement suggestions.
- Chapter 5 (Discussion) analyses and discusses the results.
- Chapter 6 (Conclusion) concludes the thesis.

Credits of the example interfaces can be found at Appendix C.

2 Background

2.1 Anatomy of an AV system

2.1.1 What is an AV system?

AV is a widely used abbreviation for *audiovisual*, which is something *involving both sight and sound* (Oxford English Dictionary 2022). *AV systems* are comprised of Audio and Video technologies and the means by which AV signals are distributed and controlled (AMX 2009).

In practice, AV systems typically consist of audiovisual devices (projectors, TV displays, video input connectors, microphones, speakers, etc.) and some way AV signals are transferred between devices (typically a cabling). AV systems can control physical devices, like whiteboards, projector screens or curtains. They might also integrate to HVAC / building automation systems and lightning control systems.

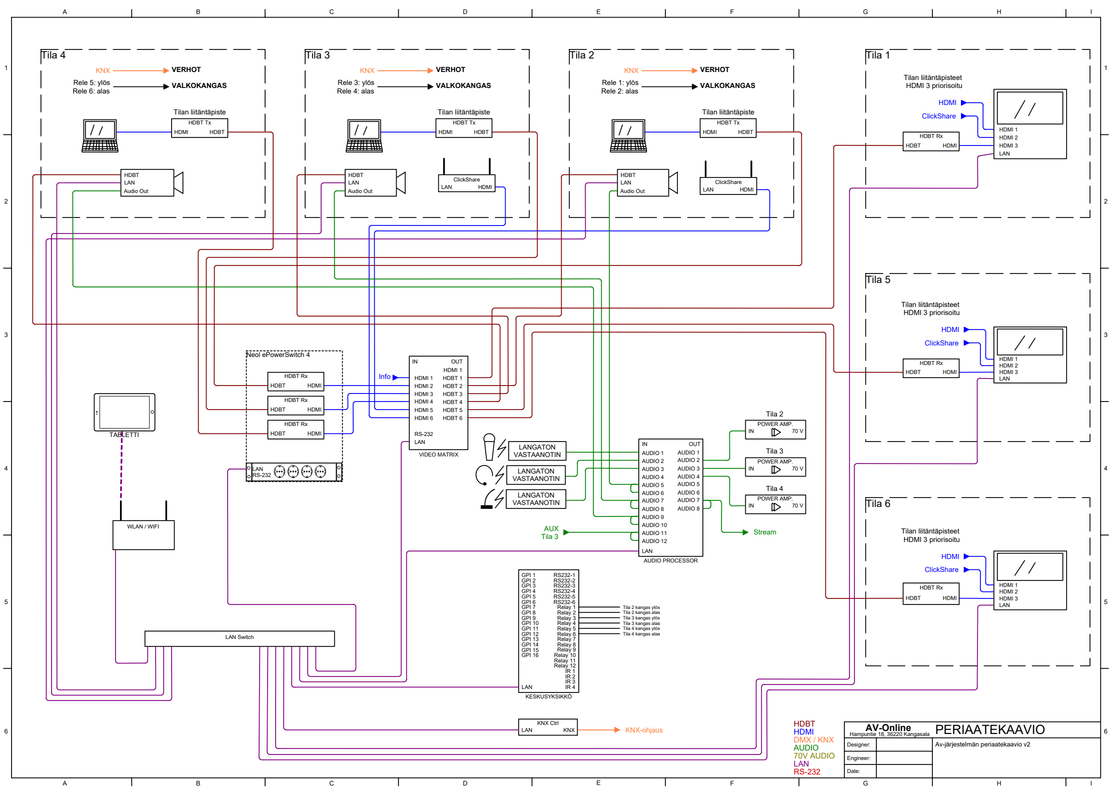

Figure 2.1 *Example system diagram of a small AV system (©Geomailer Oy)*

Traditionally, AV systems have consisted of physical devices and dedicated, separated cabling for audio, video and control signals between the devices. Nowadays it is becoming more and more common to transfer audio, video and control signals over IP (Internet Protocol) infrastructure, as it offers significant benefits compared to traditional approach (Yamauchi and Luštica 2015).

2.1.2 What is a video matrix?

A *video matrix* (or a *video matrix switcher*, or a *video router*) is a device that routes video signals from multiple input sources to one or more display devices (Wikipedia 2023). An example of a video matrix component in a small AV system can be seen in the middle of Figure 2.1.

Again traditionally, video matrices have typically been physical devices with suitable amount of video input and output connectors (HDMI or SDI, for example). In emerging AV-over-IP landscape, video routing can be virtualised so that video streams are delivered through standard IP cabling and devices (network switches, etc.) and no specific video matrix hardware is required. Instead, one could use encoder and decoder hardware to convert video signals to be transmitted over IP.

Video matrix devices and virtualised matrices can have any number of inputs (starting from two) and any number of outputs. The smallest possible video matrix configuration is *2x1*, which means it has two inputs and one output. Typical rack-mounted matrix devices have input and output configurations of *4x4*, *6x2*, *8x8* or similar, but large-scale matrices like *32x32* or even *512x512* also exist. In AV-over-IP domain, input and output counts are virtually unlimited.

2.1.3 What is an AV control system?

An *AV control system* can be thought of as a subset of AV system which is dedicated to control other devices and signals in the AV system. Main function of AV control system is to provide the user interface to the AV system. As mentioned in section 1.1, user interfaces for AV systems can be thought broadly - for example, a pile of remote controls for different devices can be thought as an AV system user interface. Ideally, an AV control system replaces this pile and controls all the devices with a user friendly, consistent user interface with an appropriate feature set. In this thesis the aim is to figure out some aspects that make the user interface usable.

AV control systems are typically proprietary solutions that consist of

- hardware *central unit*
- software to configure the system and lay out user interfaces
- physical control panel(s) to provide user interface to the users of the system

A central unit is not a necessity as AV system devices can be controlled directly using a control panel. They are still used to add connectivity, processing power and other functionality to the system and for legacy and sales reasons. In systems with multiple control panels, some kind of central unit is practically necessary.

Control panels might have physical buttons and possibly a display. It is becoming more and more typical that AV systems are controlled with tablets - either Apple or Android tablets running dedicated control application or proprietary, manufacturer-specific tablets. In this thesis, button panels are not discussed and the focus is on tablet interfaces.

Crestron is a market leader in AV control systems. Other globally major systems are *Extron*, *QSC Q-SYS*, *AMX*, *Kramer* or *Neets / BiAmp*. There are also systems by smaller manufacturers, like *DemoPad*. Typically, AV control system manufacturers produce also other AV devices (like audio processors or video matrices) that integrate smoothly into their control systems.

2.1.4 How can a video matrix be controlled?

There are multiple different approaches how to implement an user interface that routes video signals from inputs to zero or more outputs. The interaction patterns could be categorised for example as follows:

- subpages
- list of inputs
- matrix view
- drag & drop (inputs and outputs listed horizontally or vertically)
- drag & drop over floor plan

In **subpages** approach, each output has a separate subpage. An input routed to that particular output can be selected for example with buttons. An example of a subpage interface can be seen in Figure 2.2. It has two outputs - a projector and a display screen. The projector has four possible inputs and the display has three possible inputs.

***Figure** 2.2 Subpages interface (Ylä-Savon Sote, ©Geomailer Oy)*

List of inputs approach is related to the subpages approach. The main difference is that all of the outputs are listed on a single page. When an output is clicked, a list containing the possible inputs is opened. Figure 2.3 shows an example of interface based on this approach.

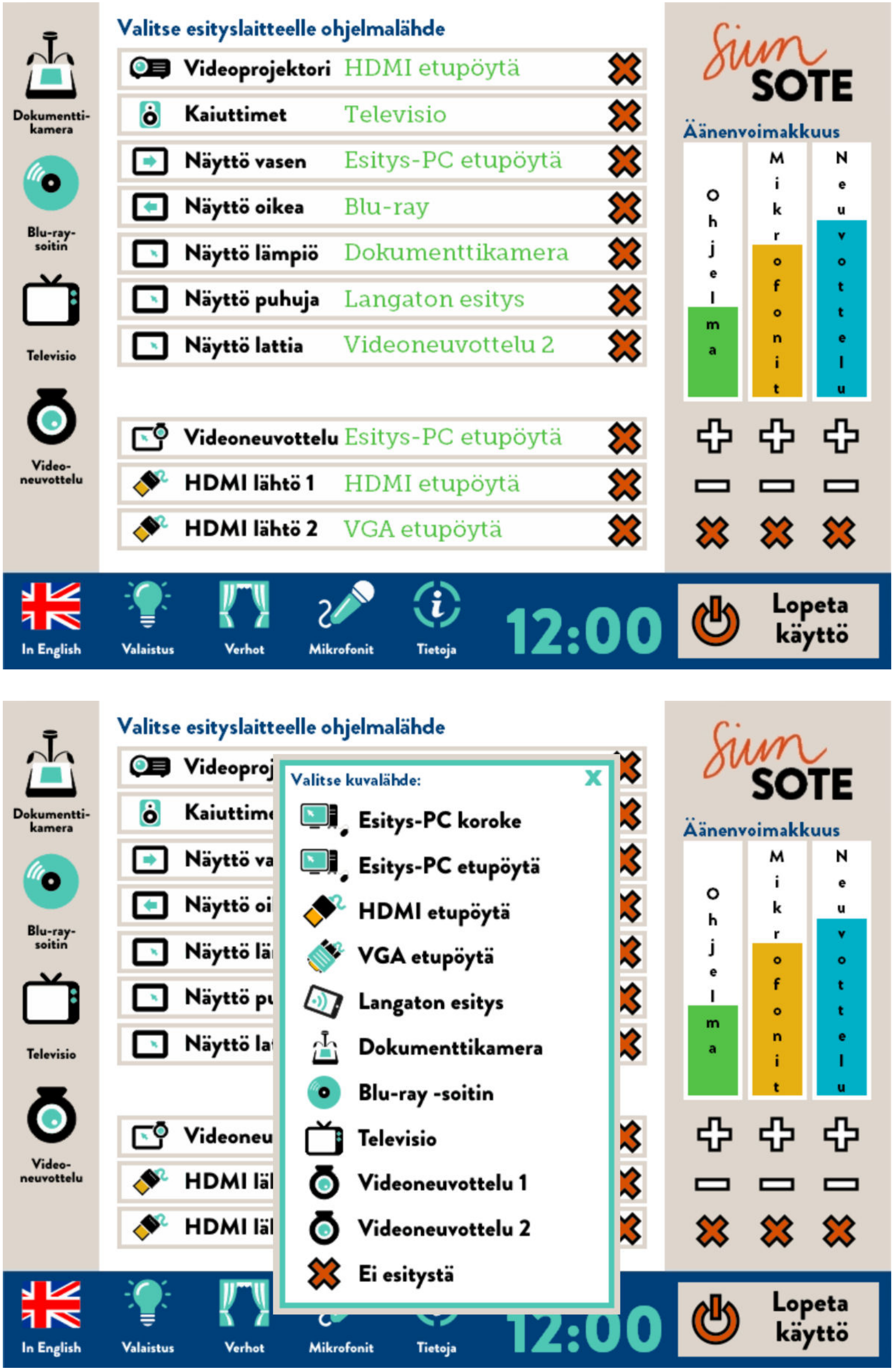

***Figure** 2.3 List of inputs interface (Siun Sote, ©Paisma avoin yhtiö)*

Matrix view is a traditional way of visualising two-dimensional data. Inputs are placed on vertical axis and outputs on horizontal axis (or vice versa) and they form a visual grid together. A symbol in a grid cell (like a checkmark in the example interface in Figure 2.4) is used to indicate that a particular input is connected to an output.

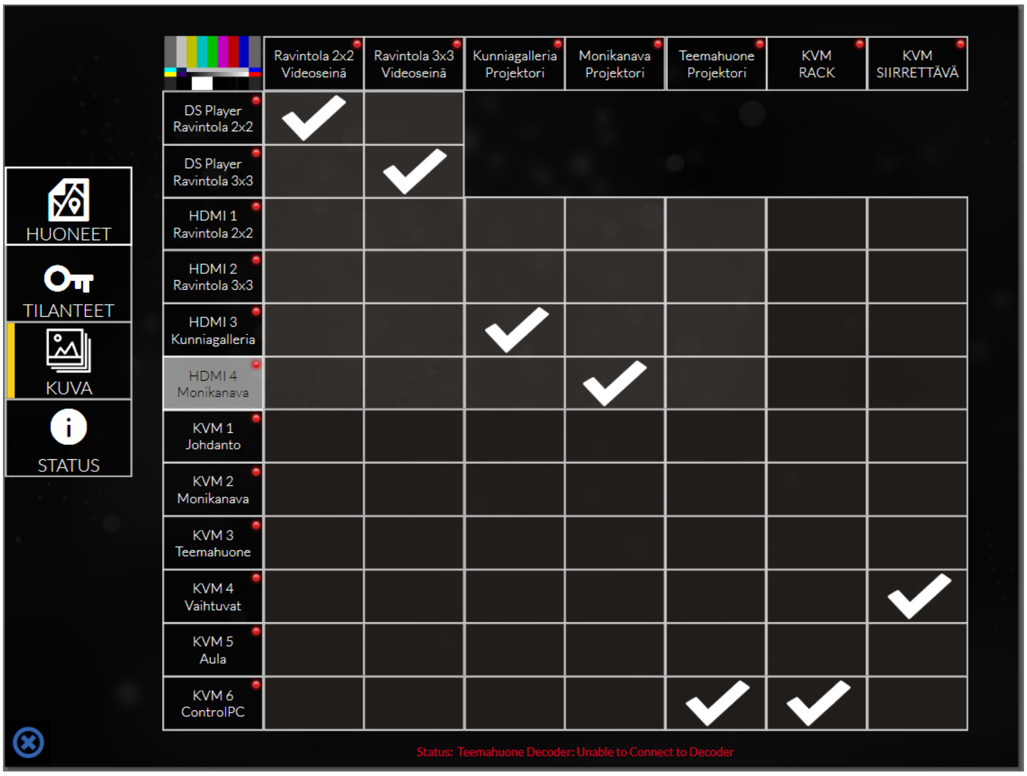

Figure 2.4 *Matrix view interface (Musiikkimuseo Fame, ©Audico Systems Oy)*

Drag & drop paradigm can be utilised with several ways in video matrix control. One way to implement a control user interface is to lay inputs and outputs horizontally and control the routings by dragging preview images from inputs to outputs. Example interface of this type can be seen in Figure 2.5. Inputs are called *transmitters* and output are called *receivers*.

***Figure* 2.5** *Drag & drop interface (©Blustream Ltd)*

Another way to utilise drag & drop paradigm is to place draggable inputs and outputs over floor plan in the user interface layout. This approach is called **drag & drop over floor plan** in this thesis. In an example interface (Figure 2.5) the dark gray icons are draggable inputs and the blue areas are outputs that inputs can be dragged onto.

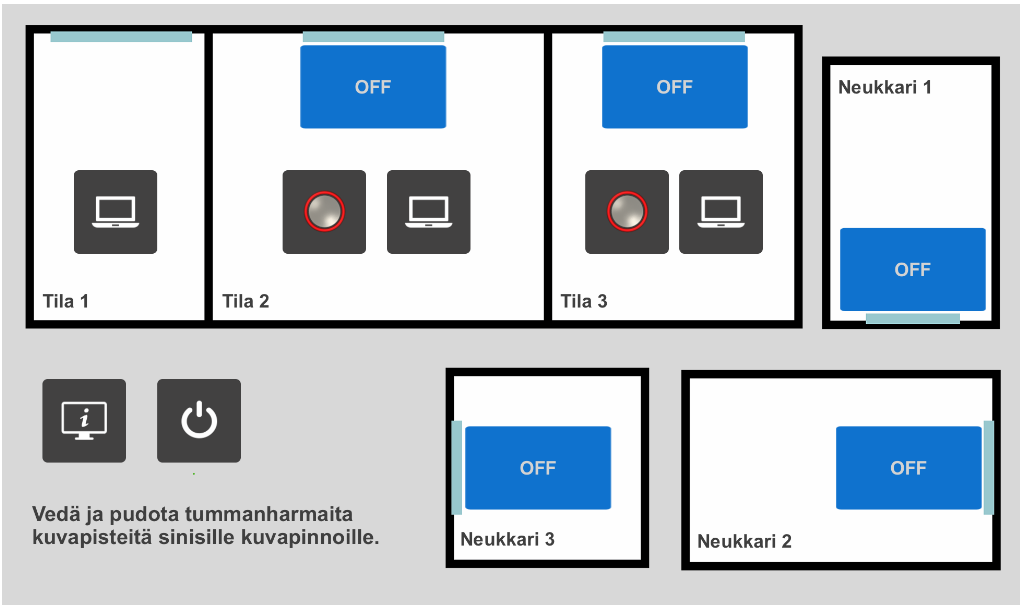

***Figure* 2.6** *Drag & drop over floor plan interface (©Geomailer Oy)*

Discussion about the aspects affecting the interaction pattern choice can be found at subsection 5.3.2.

2.2 Concept of usability

As stated in section 1.3, this thesis focuses on evaluating the usability of example user interfaces. What does term *usability* mean - how is it defined?

Historically, there has been no accepted definition for usability. Instead, there has been number of views, positions and approaches to the concept (Bevan, Kirakowski, and Maissel 1991). One historical approach is to consider and measure it as *quality of use*, as the concept of (software) quality is well defined in ISO standards (Bevan 1995).

The concept of usability has been decomposed to multiple different measurable aspects or attributes in different frameworks in literature. Examples of frequently perceived attributes include *efficiency*, *flexibility*, *learnability* and *user satisfaction* (Dubey and Rana 2010). Nielsen defines usability by aspects *learnability*, *efficiency*, *memorability*, *errors* and *satisfaction* (Nielsen 1993).

Usability has also been addressed in international standards. *ISO 9241-11* covers and defines the concept of usability and provides ways of applying it in practice. First edition was released in 1998 and revised edition in 2018. In 2003 it was evident that ISO definition is becoming the main reference of usability (Jokela et al. 2003). *ISO 9241-11:2018* defines usability as follows:

> extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use

So, ISO 9241-11 specifies usability by measurable attributes **effectiveness**, **efficiency**, and **satisfaction**. As mentioned, these three attributes are typically the deconstructed components also in other usability frameworks (Dubey and Rana 2010). These attributes are defined in ISO 9241-11:2018 as follows:

effectiveness accuracy and completeness with which users achieve specified goals

efficiency resources used in relation to the results achieved
Note 1: Typical resources include time, human effort, costs and materials

satisfaction extent to which the user's physical, cognitive and emotional responses that result from the use of a system, product or service meet the user's needs and expectations
Note 1: Satisfaction includes the extent to which the user experience that results from actual use meets the user's needs and expectations
Note 2: Anticipated use can influence satisfaction with actual use

There is also an emphasis on ISO definition that usability is dependent on *who* is using the system and *under which conditions*. So, it is necessary to take the context of use into an account (Bevan, Carter, and Harker 2015).

As a conclusion, one could simplify that based on ISO definition, usability is about how well and fast specific users are able to perform specific task(s) in specific conditions - and how do they feel about that.

2.3 Usability evaluation methods

Usability can also be seen through two major conceptions: *summative* and *formative*. The focus of summative usability measurement is on metrics associated with meeting global task and product goals (measurement-based usability). The focus of formative usability is the detection of usability problems to reduce or eliminate their impact (diagnostic usability) (J. R. Lewis 2014).

ISO approach presented in section 2.2 bases on summative conception, as it provides measures to evaluate usability based on completeness and efficiency of specific goals. Formative conception relies on (possibly iterative) process of eliminating usability problems and presence of usability depends on the absence of usability problems (J. R. Lewis 2014). Formative evaluation focuses on solving problems before final design is released, and summative evaluation is then conducted to evaluate the efficacy of the final design (Hartson, Andre, and Williges 2001). Kies, Williges, and Rosson 1998 position the execution of formative and summative evaluation in iterative design process as seen in Figure 2.7.

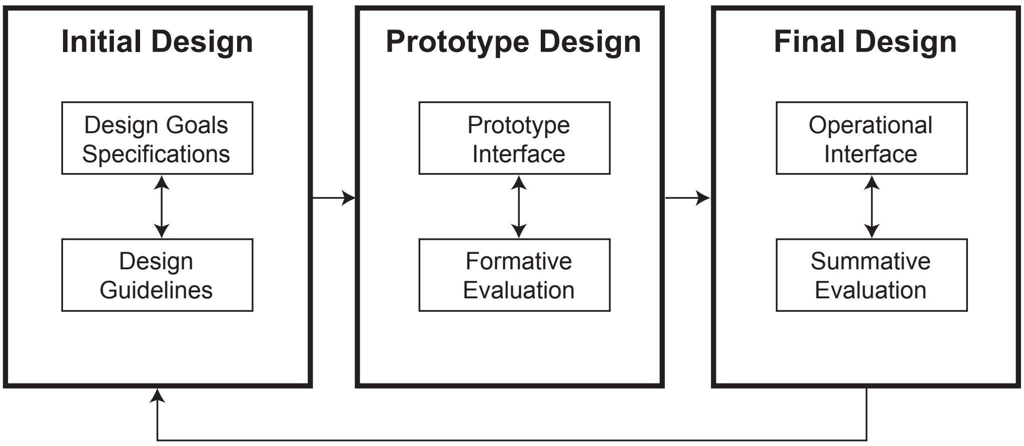

Figure 2.7 *Formative and summative evaluation in iterative design process (Kies, Williges, and Rosson 1998)*

This section introduces some popular evaluation methods and strategies relevant to the study and discusses briefly their pros and cons. This is not intended to be a comprehensive study or comparison, as it is beyond the scope of the research.

2.3.1 Formative methods

Heuristic evaluation, *cognitive walkthrough* and *expert review* are examples of usability evaluation methods based on formative conception (J. R. Lewis 2014). They can also be called *usability inspection methods* (Nielsen 1994).

Jacob Nielsen, a pioneer of **heuristic evaluation**, defines the concept briefly: "heuristic evaluation is done by looking at an interface and trying to come up with an opinion about what is good and bad about the interface" (Nielsen 1990). Heuristic evaluation is conducted by having a small set of evaluators examining the interface and judging its compliance with recognised usability principles (Nielsen 1995). Nielsen's 10 heuristics have remained unchanged since 1994 (Nielsen 2020). They are as follows (Nielsen 1994):

1. Visibility of system status
2. Match between system and the real world
3. User control and freedom
4. Consistency and standards
5. Error prevention
6. Recognition rather than recall
7. Flexibility and efficiency of use
8. Aesthetic and minimalist design
9. Help users recognise, diagnose, and recover from errors
10. Help and documentation

There are also other lists of heuristics (like Gerhardt-Powals 1996) or usability principle lists composed from multiple sources (like Weinschenk and Barker 2000). Nielsen's heuristics are widely used, but can be thought to be too general for some purposes (Jimenez, Lozada, and Rosas 2016). It is also possible to create domain-specific set of heuristics. Hermawati and Lawson 2016 compared studies utilising domain-specific heuristics of which 83% were using heuristics some or all similar to Nielsens.

A procedure of **cognitive walkthrough** was introduced in same conference with Nielsen's heuristic evaluation by C. Lewis et al. 1990. As heuristic evaluation, cognitive walkthrough is a structured way of evaluating interfaces by discovering usability problems. It is based on model of learning by exploration called CE+ (Polson and C. Lewis 1990). Cognitive walkthrough focuses on learnability of interface from new users' perspective (Salazar 2022).

On the first phase of CW process (preparation) the tasks and actions required for their completion are defined. On the second phase (evaluation) each action is inspected by answering the specific questions related to that action. As the original version(s) of the process were awkwardly time-consuming, multiple revised versions and variants have been created. Mahatody, Sagar, and Kolski 2010 have researched the evolution of cognitive walkthrough methods.

Both cognitive walkthrough and heuristic evaluation rely on expertise of a set of reviewers (Salazar 2022). Usability specialists are better than non-specialists at performing heuristic evaluation (Nielsen 1992). There is also less structured way to evaluate usability relying on evaluators expertise: **expert review**. Expert reviews expand on heuristic evaluations by assessing the design not only for compliance with specified heuristics, but also against other known usability guidelines and the reviewer's expertise and past experience in the field (Harley 2018).

2.3.2 Summative methods

As formative methods focus on improving product by eliminating usability problems in development time, **summative evaluation methods** aim to measure usability of a product at certain stages of production (Kirakowski 2005).

Pioneer of summative usability measurement was MUSiC project (Bevan, Kirakowski, and Maissel 1991) which focused on developing tools for measuring effectiveness, efficiency and satisfaction (Bevan 1992). The output of the project was a consistent set of methods, software tools (DRUM) and measures (SUMI) that responded to market needs of assessing the usability of products (Bevan and Curson 1997, Kirakowski 1995).

Hornbæk 2006 has analysed 180 studies measuring effectiveness, efficiency and satisfaction of use and provides analysis about variety of measurement methods. Effectiveness is measured by for example a binary task completion (do the tasks get completed), an accuracy (error rates, spatial accuracy, precision), a completeness of tasks or a quality of outcome. Efficiency is most often measured by a time to complete a task. Satisfaction could be measured by standardised questionnaires, ranking/rating multiple interfaces by preference or asking questions related to the user satisfaction towards the interface.

Hornbæk 2006 also points out a distinction between *objective* and *subjective* nature of usability measurement. For example, efficiency can be measured objectively by measuring a time to complete a task, or subjectively by measuring the experienced duration to complete a task. The experienced duration might differ even though objective measured time was fixed (Tractinsky and Meyer 2001).

2.3.3 Usability testing

A typical setup to gather information about usability is to perform an **usability test**. In usability testing, the interface is studied under real-world or controlled conditions, with evaluators gathering data on problems that arise during its use (Jeffries et al. 1991). Usability testing can be summative or formative by nature, depending on a goal and methodology. There are different types of usability tests: formative problem discovery, measurements (comparison against quantitative objectives or other products) or other types such as think aloud or testing in usability laboratories (J. R. Lewis 2012).

Usability testing could be combined to expert reviews and heuristic evaluation. Usability testing may uncover issues that an expert may have not thought of — for example, because the real audience has very specific knowledge or needs (Harley 2018).

Usability testing is generally expensive and time-consuming when compared to other methods in formative domain (Jeffries et al. 1991). Molich, Ede, et al. 2004 have compared different summative and formative usability tests and found out that there was only a little overlap in found usability problems, which raises the question about the "objectivity", comprehensiveness or completeness of any single testing method, procedure or setup.

2.3.4 Sample sizes

There is a lot of discussion about optimal sample sizes for usability evaluation.

Sample sizes for formative evaluation are typically quite low. There are some "magic numbers" about optimal participant count. They range from 3-5 (Nielsen and Landauer 1993, Nielsen 1995) to 8 to 10 (J. R. Lewis 2014, Hwang and Salvendy 2010), depending on the participant abilities, etc. Optimal participant count can be determined using mathematical methods (J. R. Lewis 2006, J. R. Lewis 2014).

Sample sizes for summative methods are typically larger than for formative methods. Kirakowski 2005 concludes that summative testing sample sizes are typically between 12 and 20 users per test (sometimes many more). J. R. Lewis 2014 states that a common rule of thumb for summative usability tests, based on a common convention in applied statistics, is to have a sample size of at least 30.

2.4 Usability of AV systems

The definition of usability and approaches to evaluate usability are covered above in general level. Is there any literature or theory specific to AV systems?

It seems that there are very little, if any (Myller 2011). There exists lots of research about technical aspects of AV systems, but not about usability of AV systems (Hokkanen 2010).

General usability theory and methods can be utilised in specific domains. For example, custom heuristics may be created to evaluate usability of devices or buildings (Hermawati and Lawson 2016).

Based on interviews (with Kantoniemi, Mäenpää and Sivonen, 2023) one gets an impression that a theoretical background and frameworks related to usability have been utilised scarcely (but increasingly). Typically, AV systems have been specified so that the usability is not a top priority - and they are implemented by programmers and/or people that are not necessarily specialised in usability. Principles leading the design might have been based on a personal experience and instinct instead of research. A personal ambition has been a typical motivator to increase the focus on usability.

Kantoniemi suggests that one could utilise for example website accessibility principles and requirements also in AV system user interface design. However, Sivonen mentions an example case where an AV system user interface had been designed together with usability professionals previously focused on tablet app interfaces. This iterative process led to a knowledge about differences in practical principles of user interface design for tablet apps and AV systems, concerning for example font sizes.

As a conclusion, one could see the justified need for actions that connect general usability research and AV system design practices.

3 Methodology

3.1 Interfaces being evaluated

In this thesis three example interfaces will be evaluated. This is a subset of all of the interfaces the author has designed and implemented for Geomailer Oy during the last few years which meet the following criteria:

- the video matrix is controlled by *drag&drop over floor plan* paradigm
- the AV system is still in daily operation

Evaluated part of the interfaces is used to control the video matrix - ie. to choose which output is displaying which input. The same interface is also used to control power-on status of the projectors or displays. The interfaces are running on Apple iPad tablet running DemoPad CentroControl AV control system. Tablet screen size is around 10" (depending on a model).

All of the three interfaces are based on the same paradigm. A gray button represents a video input, like an HDMI connector or ClickShare screen sharing device. They are positioned over a floor plan according their physical location, when applicable. If an input does not have a meaningful physical location (input of a hotel info channel, for example), it is positioned outside of the floor plan area. Blue squares represent video outputs, ie. displays. They are also positioned according to their physical locations. Routings are applied by dragging & dropping input buttons over output areas.

The idea behind this approach is to provide a direct mapping between physical inputs and outputs and their counterparts in an user interface. Other option would be to name or label the inputs and outputs. This would require the users of the system to figure out where an input or output of a particular name is located physically. The end result of the "over floor plan" approach is assumed to be clearer for at least novel users.

Even though all of the interfaces share a similar operating principle, they have some differences. Implementation of *Interface 2* is a bit older than the others. It does not have laptop icons in HDMI input buttons - the input numbers are used instead. In these particular conference rooms there are five HDMI inputs located in a relatively small space, so it was considered reasonable to use a labelling (numbers 1...5) to clearly distinct them from each other. Nevertheless, the idea of using icons in inputs buttons came up later. *Interface 3* has more inputs and outputs and therefore a bit more complexity than the others.

Despite the differences, all of the interfaces can be considered similar in that sense that the insights gained about one interface can be mainly applied to others as well.

All of the evaluated AV systems are located in conference facilities of either one of major Finnish hotel chains (Sokos Hotels or Scandic Hotels). The use case can be described as follows. Hotel conference/meeting rooms are rented to third-party guests for some hours or days. Before their session stars, hotel employees (conference hosts) set up the AV system based on guests needs. As defined in original AV system design requirements, all of the interfaces are operated by hotel personnel - not by conference visitors or customers.

Typically, a manual of some kind (at least a "simple user manual" with some screenshots) is required as a part of the delivery of AV system. In case of these three particular AV systems, no manual was required or delivered. Instead, a short training was given to the hotel personnel about how to operate the system.

The language of user interfaces is Finnish. Interfaces are evaluated in Finnish to avoid translations to have any effect. Here are translations of user interface texts.

tila	a space
neukkari	a meeting room
Vedä ja pudota tummanharmaita	Drag and drop dark gray inputs over
kuvapisteitä sinisille kuvapinnoille	blue outputs
projektori	a projector
näyttö	a display
Lähetä ohjelma ravintolaan	Send program feed to the restaurant

3.1.1 Interface 1

Location	Conference facilities of a hotel located in Kuopio, Finland
Installed	July 2021
Spaces	Three combinable spaces & three separate meeting rooms
Inputs	6 (3x HDMI connectors, 2x ClickShare, 1x Info screen)
Outputs	5 (2x projector, 3x display)

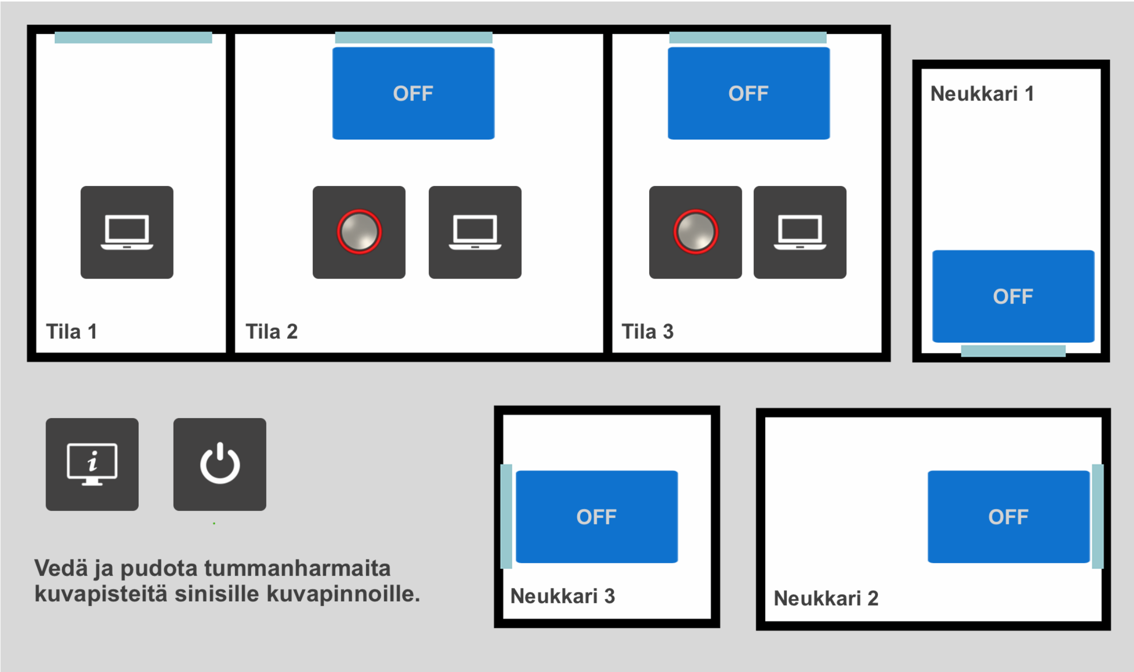

Figure 3.1 *Interface 1 (©Geomailer Oy)*

Spaces 1, 2 and 3 can be combined or separated with curtains. Each space has an HDMI input and two of the spaces have ClickShare screen sharing devices. Three fixed meeting rooms can be used individually with a remote control or inputs of the combinable spaces can be routed to the meeting rooms. Hotel info screen can also be routed to any display.

Projectors and displays power on automatically when an input is dragged over them. They can be powered off manually by dragging the power symbol over them.

3.1.2 Interface 2

Location	Conference facilities of a hotel located in Vaasa, Finland
Installed	March 2018
Spaces	Two combinable spaces
Inputs	8 (5x HDMI connectors, 2x ClickShare, 1x Buffet HDMI)
Outputs	5 (3x projector, 1x display)

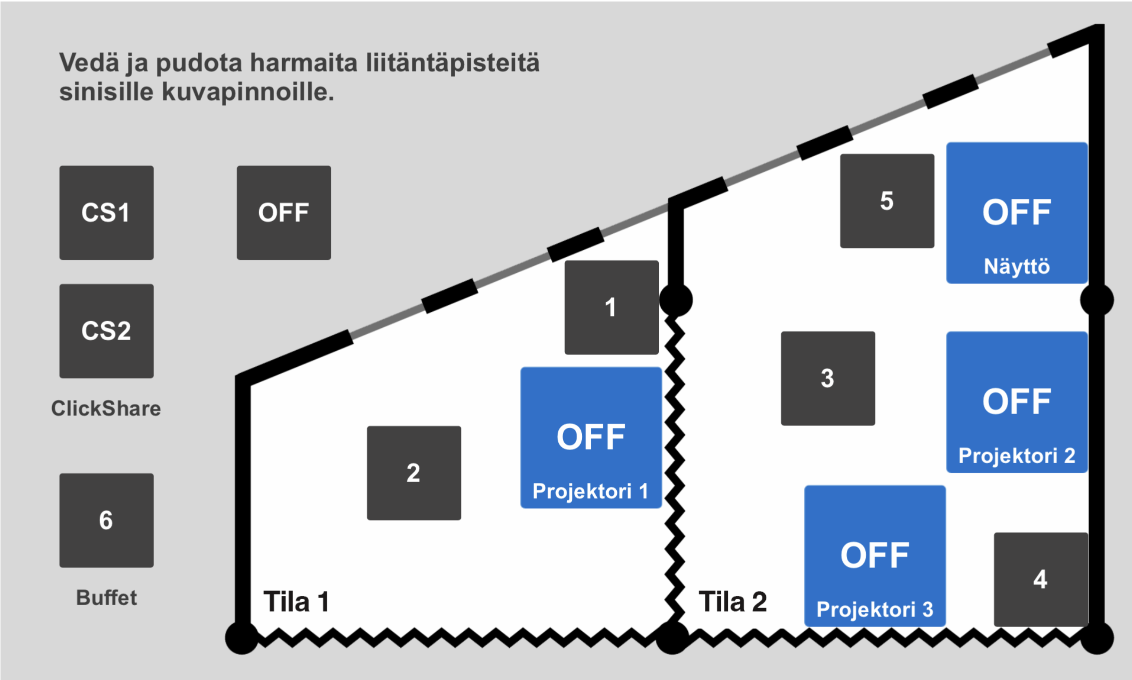

***Figure* 3.2** *Interface 2 (©Geomailer Oy)*

Two spaces can be combined with curtains. When separated, they can be controlled by a specific user interface that affects only that space. When the spaces are combined, this particular interface is used to control input and output routings. There are five HDMI input connectors located in the space. They are located physically as positioned in the interface. One HDMI connector (Buffet) is located physically outside the area. Additionally, there are two ClickShare screen sharing devices that can be routed to the outputs.

Space 1 has a single projector. Space 2 has two projectors and one display. Projectors and displays power on automatically when an input is dragged over them. They can be powered off manually by dragging the power symbol over them.

3.1.3 Interface 3

Location	Conference facilities of a hotel located in Joensuu, Finland
Installed	October 2021
Spaces	Eight combinable spaces
Inputs	7 (4x HDMI, 1x ClickShare, 1x Camera, 1x Restaurant)
Outputs	11 (6x projector, 4x display, 1x stream)

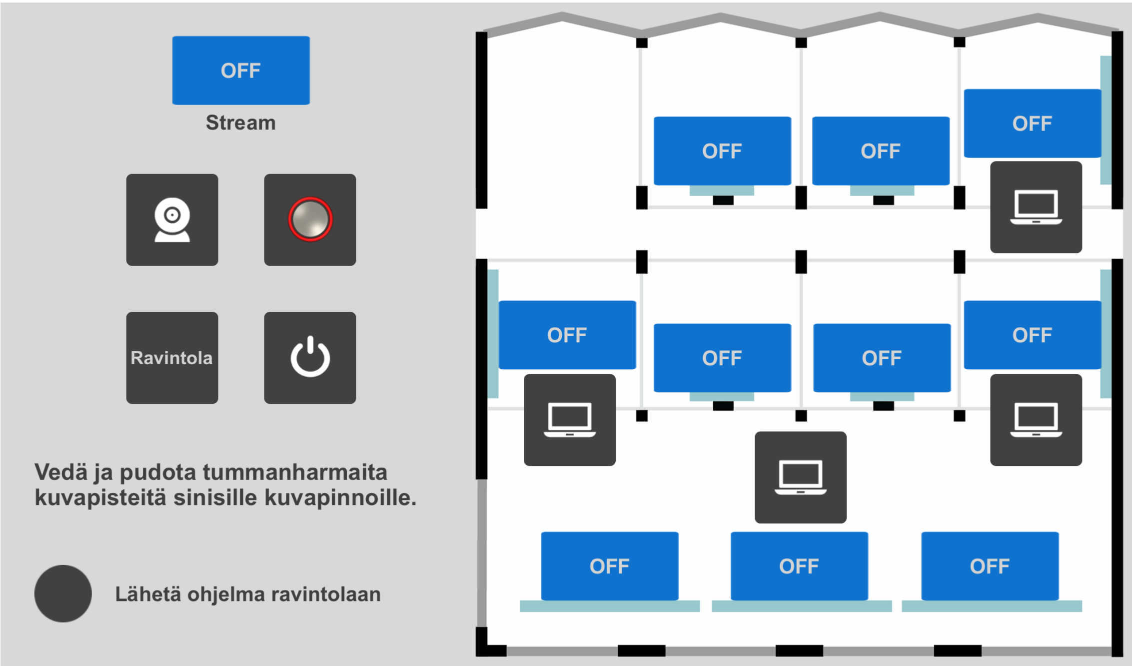

Figure 3.3 *Interface 3 (©Geomailer Oy)*

The hotel conference facilities consist of eight different spaces that can be combined or separated with curtains multiple ways. Each allowed combination has a dedicated interface. This particular interface is for the combination where all of the curtains are open and the whole space is combined to be used as a single area.

There are six projectors and four displays in the area. Also, any input can be routed to a streaming device. Four HDMI connectors, a ClickShare screen sharing device, a video camera and a program feed from the restaurant building can be used as inputs. Also, the input routed to the main projector can be fed to the restaurant building to be used as an input there.

3.2 Usability attributes

If one considers the concept of usability as it is defined in ISO 9241-11 (section 2.2)...

> extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use

...one can think that in the case of these three interfaces, one can effortlessly define the the following:

specified users	dedicated hotel employees (conference hosts)
specified goals	controlling video routing from inputs to outputs
specified context of use	daily work in hotel conference area

On the other hand, even though **specified users** can be defined strictly as *conference hosts*, there might be a large variation of *personas* using the system in conference host position. Actual users might differ by background, gender, age, nationality and technical skill level. Then, as operating the AV system is a major part of their job description, one might employ only people technically oriented enough to be able to effortlessly operate the system.

Based on a personal experience on installation sites and a communication with clients after installations, one thing seems to be common for conference hosts: their work consists of hassle and is sometimes very hectic. They do not typically have extra time to struggle with extra problems related to the AV system.

Specified goals are controlling video matrix inputs and outputs so that one can select which video input is routed to which video output (displays or projectors). Also the interface is used to turn the displays and projectors on and off.

Specified context of use is framed by the daily work in a hotel conference area. Physically the environment is stable: an interior space with static properties and well-defined and stable technical environment. However, changing customers and sometimes hectic atmosphere shape the mental context of use.

The aim is to evaluate **effectiveness, efficiency and satisfaction** of specified users using the system.

3.3 Chosen methods

As described in previous chapters, there are quite a many possibilities to evaluate the usability of a user interface. Next step is to choose most suitable ones taking account the scope of a Master's thesis.

Based on the literature review performed in chapter 2, it seems to be natural to evaluate usability of an actual, operational product with a summative approach. The chosen metrics could be the widely accepted ones standardised in ISO 9241:11 (Bevan, Carter, and Harker 2015), with conditional clauses that make measurement meaningful (Kirakowski 2005) as specified in section 3.2.

There are, however, some limitations that affect the chosen methodology. As one can see in section 3.1, there are only few (three) users that are actively using the systems in specified context of use. This is in a contradiction with the nature of summative evaluation which is considered to lean into quantitative side with larger sample sizes to be statistically valid (subsection 2.3.4). Also, the users in question are busy and are most likely not willing to participate in time-consuming research activities.

That makes to consider carefully how to conduct the research with actual users. It was ended up creating a very brief questionnaire which tries to address the usability attributes and gain information about the usage of the system. The goal was also to sense if the users are willing to be interviewed afterwards to gain some more unstructured insights about the usability of the systems.

It was also considered to perform usability testing with participants that are not actual users of the particular AV systems, but choosing the participants so that the other conditional clauses are met. However, there were some practical limitations preventing this approach. The spaces running the actual systems are quite booked and they are located more than 250km from Tampere, which makes it too expensive for participants to travel and too hard to recruit enough local test users. It was also thought to build a similar real-world environment here in Tampere for testing purposes, but it would have been too expensive as the corresponding AV equipment required would cost tens of thousands of euros.

As it was evident that it is likely that summative approach would not provide enough information, the methodology had to be extended. If one looks at the goals of the research specified in section 1.3, one can see that the aim is to evaluate the interfaces but also to improve the interfaces created later with same pattern. Formative methodology would provide tools to improve interfaces by revealing usability problems.

Based on Hartson, Andre, and Williges 2001, heuristic evaluation is a cost-effective way to implement usability evaluation when compared to user testing methods, which would require active recruitment of participants and significant time to carry out. Heuristic evaluation is a widely popular method for discovering the sources of trouble of usability problems (Dhouib et al. 2016) and was also here a natural choice to gain information.

Usability specialists are better than non-specialists at performing heuristic evaluation, and *double experts* with specific expertise in the kind of interface being evaluated perform even better (Nielsen 1992). Based on that point of view, the priority was to find suitable people with enough "double expertise" both in usability and AV technology to find meaningful insights and relevant problems in heuristic evaluation.

Another way to utilise double expertise is to perform an expert review on the interfaces. Expert review can be thought as a more general version of a heuristic evaluation (Harley 2018). There was a chance to let AV control system professionals to evaluate the interfaces and that possibility was utilised.

Performing a cognitive walkthrough was also considered, but rejected. In the task being evaluated (routing video inputs to outputs) there are not much sub-actions and the method was too formal for evaluating such a simple task.

3.4 Description of methods

As reasoned in section 3.3, the following three methods were used to evaluate the interfaces.

- **User questionnaire** to actual users of the system
- **Heuristic evaluation** by usability specialists with knowledge of AV systems
- **Expert review** by AV system and usability experts

3.4.1 User questionnaire

The main issue was how to design the questionnaire so that it gives some measurable data about effectiveness, efficiency and satisfaction taking into account constraints described in section 3.3.

Hornbæk 2006 has gathered extensive aggregation of summative studies measuring these attributes. Based on that research, it seems that effectiveness is practically never measured by questionnaires. Measuring effectiveness would require controlled user testing. Same applies to measuring efficiency, which is typically measured by measuring time it takes to complete the tasks. This kind of measurements were not possible in this case.

Satisfaction, however, is typically measured using questionnaires (Hornbæk 2006). There are many different (standard, or - more likely - non-standard) measures applied. Hornbæk points out that while satisfaction is measured with some standardised, comparable way like QUIS (Chin, Diehl, and Norman 1988) in some studies, in most of the studies it is measured by assessing some "clever" attribute from a huge pool of adjectives or adverbs in Likert-type rating scale. This thesis continues this somehow questionable tradition by choosing yet another adjective to assess in Likert scale.

Despite that effectiveness and efficiency are typically not measured by questionnaire, the goal was still to gain some information about them by wording the question so that it would give at least some insights. As stated in subsection 2.3.2, one could evaluate *subjective* efficiency or effectiveness - the users' experience about these attributes. So, it was ended up wording the main question so that it would focus on gaining information mainly about satisfaction of use, but also some insights about effectiveness and efficiency. The main question goes as follows:

How smooth/fluent it is experienced to select the video inputs? (1 = very cumbersome, 7 = very smooth/fluent)

The questionnaire sent to users (Appendix A) was written in Finnish. The translation above is a bit clumsy as it tries to retain all of the meanings of the original question. Finnish word *sujuva* translates into *smooth/fluent*, so the aim is to measure subjective, experienced "smoothness"/"fluentness" of use. It might not be relevant here to go too deep into semantics of at least these translated adjectives. Based on general sense of language, one would not assess system to be smooth/fluent to use if it is not efficient, effective and satisfactory to use - and vice versa - efficient, effective and satisfactory system could be considered smooth/fluent to use.

Additionally, besides of gaining information on experienced smoothness of usage, there was also other aims for the questionnaire. Strategy was to start with very simple, quick and easy-to-answer questions to get at least some insights. If there was any perceptible willingness, the conversation could be extended with further questions or maybe an (unstructured) interview. One point was to motivate users to list usability problems by pointing out that they could be fixed afterwards as a separate project. The final, translated questions (and the motivations for the questions in italics) were as follows:

1) Who are main users of the system? (f.ex. conference clients, hotel employees, ...)
To verify the assumption made in section 3.1 that interfaces are used mainly/only by hotel employees

2) How smooth/fluent it has been to use (AV) system in general? (free-text answer)
To gain free-form information of the experience about AV system in general (and to "warm up" the user)

3) How smooth/fluent it is experienced to select the video inputs? (1 = very cumbersome, 7 = very smooth/fluent)
Main question (as described above)

4) Any ideas about how to improve video input selection or system in general? (free-text answer)
To gain (formative) improvement ideas from users

The questions were sent to users via email. Email contacts of users were obtained by the help of a contractor.

3.4.2 Heuristic evaluation

First thing was to decide which heuristics the evaluation is based on. As discussed in subsection 2.3.1, heuristics can be customised for specific domain. Initial thought was to use Nielsen's popular list of heuristics as a base but modify it so that it better suits this particular case. However, after consideration it was decided to use Nielsen's list of heuristic as is. Despite of some potential flaws like it considered being too general, it is widely utilised and validated itself well over time. All of the heuristics suit this case quite well, and it seems there is not any domain-specific usability aspects that should be taken into account.

As stated in subsection 2.3.4, sample sizes may vary and could also be mathematically determined. In this case, it was sticked with an impression of Nielsen 1995 that recommendation is normally to use three to five evaluators since one does not gain that much information by using larger numbers. In this particular case the interfaces being evaluated are very simple. Additionally, expert reviews are performed to gain corresponding information. These two methods overlap and together raise the probability of finding a particular usability problem.

Evaluators were recruited among the circle of acquaintances of the author. The participating evaluators were chosen so that they meet the following criteria (to utilise *double expertise*):

- They have a solid experience in software development
- They have some experience in software usability and user experience
- They have a good understanding about AV systems
- They are easily accessible

The link to Nielsen's heuristics was sent to evaluators beforehand, so that they can get theirselves familiar with the concept. The actual evaluation was conducted applying the procedure stated by Nielsen 1995. Observer (thesis author) and evaluator gathered to a same room. First a printed "poster" of Nielsen's heuristics and a briefing document (section B.1) were handed to an evaluator so that all of the evaluators received the same background information about the user interfaces at the same point in timeline. Then the evaluator started evaluating the system based on the heuristics above. The observer took notes of all the found usability problems and they were linked to one or more heuristics. Problems were categorised being specific to a single interface or general (concerning all of the interfaces). The severity of problems were rated from 1 to 5 as follows

1=just a tiny problem
5=prevents the usage of the system

Finally, the correctness of notes was verified by the evaluator and the evaluator self-assessed his/her background with following attributes.

- Job title
- Years doing software development work
- How much focus you have had on usability / user experience in software development work? *(0=none ... 5=all the time)*
- What is your level of understanding about AV systems? *(0=none ... 5=professional level)*

After each of the sessions, the notes were dissembled to a log spreadsheet. They were sent to the participants to let them quickly verify that no wrong interpretations were made during the disassembly. After that, all the logs were merged to a single spreadsheet. For each problem, the cost to fix the problem was roughly estimated by scale 1 (practically free) ... 5 (expensive). Then, all of the problems and improvement suggestions were sorted by *feasibility*, which was assessed by the author based on severity and estimated expense.

Finally, a remote "debriefing session" (as suggested by Nielsen 1995) was organised with all of the participants in a WhatsApp group. The idea was to give the evaluators a chance to read through each others' evaluations and discuss about them and the evaluation process in general - and to possibly output some more insights.

3.4.3 Expert review

The expert reviews were carried out supplementary to the heuristic evaluation. Two experts were approached based on recommendations regarding their positive attitude towards AV system usability.

Harley 2018 outlines the typical process and outcome of expert review, which could be a document containing a list of usability problems ranked by severity, recommendations for fixing the problems and best practices to guide improvements. However, Molich and Jeffries 2003 operate with wider zoom and define expert review as "an ad hoc method used by one or more expert usability professionals to evaluate a user interface. The only thing you can say about it is that it doesn't require users other than the reviewer(s)."

The latter, informal approach was used here, mainly because the experts chosen did not get paid and it seemed more than reasonable to minimise the time spent with formalities. The process was very free-form. AV control system user interface was launched on tablet. Very short brief was given so that the experts could get familiar with the use case, equipment and idea and the physical space of the location. Then, the experts started exploring and commenting the user interface based on their experience about AV control systems. The audio of the sessions was recorded and later transcribed and dissembled to the Result chapter (section 4.3).

It was not explicitly stated, but the goal was to gather any kind of impressions, not just usability problems. As Harley 2018 says, to make reviews less "doom and gloom," and ensure that good design elements are not marred in the redesign process, the review should also include a list of strengths.

3.5 Research ethics

System users, heuristic evaluators and expert reviewers were anonymised to protect their identity against exposure to unwelcome types of scrutiny (Shklovski and Vertesi 2013).

Heuristic evaluators, expert reviewers and interviewees were given a chance to read through their comments and observations before the release of the thesis to be able to react to possible mistakes, misunderstandings and misinterpretations in transcription and logging.

4 Results

4.1 Results of user questionnaire

The user questionnaire was conducted by sending the questions presented in subsection 3.4.1 to the users of the three interfaces introduced in section 3.1 via email. User of Interface 1 is referred as *User 1*, and so on. The questions sent to the users and the email responses can be found in Appendix A.

4.1.1 Timeline

The initial questions were sent to users on *16th of February, 2023.*

User 2 responded quickly. Initial contact person was on maternity leave, but her substitute delegated questions to responsible person who responded in a couple of days.

User 3 responded after a reminder, which was sent on *6th of March, 2023.* *User 1* responded soon after a second reminder which was sent on *18th of April, 2023.*

4.1.2 Responses

The first question was about the actual users of the system. The aim was to verify the assumption that it really is the hotel personnel who is mainly using the system.

Every user stated that the actual situation is as assumed. The case with all of the users is that the hotel personnel prepares the space to be fully ready for the clients. However, *User 2* mentioned that the system is "easy and simple (...) for some of our clients" also, which implicitly states that the clients are also using it at some cases. Also, *User 3* mentioned that the clients use the system "only when necessary". So, there is another indication that the system is also used by the clients at some level, in addition to the hotel personnel.

The answers to the second question *How smooth/fluent it has been to use (AV) system in general?* were unanimous.

- *User 1:* Very simple and smooth.
- *User 2:* The systems function smoothly. It is easy and simple to navigate (...).
- *User 3:* Everything has gone mainly well.

Third question was the "main question": *How smooth/fluent it is experienced to select the video inputs? (1 = very cumbersome, 7 = very smooth/fluent).* Again, the answers were flattering towards the usability of the system.

- *User 1:* 7
- *User 2:* 7
- *User 3:* 6

Finally, fourth question was about improvement ideas about the video matrix control or the AV system in general. *User 1* and *User 2* did not mention any improvement ideas but stated that system is very clear and it is good enough for the purpose. *User 3* had a well justified improvement idea:

> Sometimes it would be easier to operate displays especially in larger [combined] spaces if area names were mentioned in the layout. It is not always clear that user is holding the device right way, and he/she might accidentally choose adjust wrong output.

All of the results are discussed in chapter 5.

4.1.3 Further actions

Based on the insights gained when co-operating with conference hosts in different projects, there were doubts that their daily work is so busy that it does not allow participating in extensive research activities. Still, there was some hope that questionnaire could be extended with f. ex. unstructured interviews, if hints of willingness to participate was visible.

All of the three answers were very co-operative and polite. However, no actions were done to gain extra information. It was justified by a couple of viewpoints. All of the users were so satisfied with the system that "squeezing" extra information about possible weaknesses of the system could possibly have changed their attitude towards the system to a negative direction. The only user who did not give maximum grade did already provide a suggestion to improve the system. Also, two of the users answered after one or two reminders, which indicates that this research was not in a high priority in their schedule.

Therefore, no further actions with users were done. The research proceeded with the heuristic evaluation and expert reviews.

4.2 Results of heuristic evaluation

The heuristic evaluation sessions were conducted May-June 2023. They provided valuable insights about usability problems of the interfaces.

4.2.1 Participants

Before starting to conduct the evaluations, five evaluators were chosen. However, during the process it was noticed that there were such a many thematically similar problems found that two estimates were made (based on statistical model described by Nielsen 1993):

- N (number of total usability problems) is low. This is justified as the evaluated system is rather small-scale.
- λ (probability of an evaluator to find a single usability problem) is high. This is justified as the evaluators are experienced and have double expertise.

Therefore, and taking also into account that there were also expert reviews conducted, it was considered wise to save resources and stick with only three evaluators. It was probable that conducting evaluations with remaining two evaluators would not significantly help to find new major usability problems.

The evaluators self-assessed their work history and related skills as follows:

1. Job title
2. Years doing software development work
3. How much focus you have had on usability / user experience in software development work? *0=none. . . 5=all the time*
4. What is your level of understanding about AV systems? *0=none. . . 5=professional level*

	1. job title	2. years	3. UX	4. AV
Evaluator 1	Software Developer	8	4	3
Evaluator 2	Principal Architect	20+	4	3
Evaluator 3	Software Architect	10+	4	4

Table 4.1 *Heuristic evaluation participants*

4.2.2 Results

Total of 34 usability problems or improvement suggestions (later called simply *problems*) were found by evaluators. *Evaluator 1* found 8 problems, *Evaluator 2* found 11 problems and *Evaluator 3* found 21 problems. Assessed severity of the issues ranged from 1 to 4, median being 2 - no "showstoppers" were found. Individual findings are listed in section B.2.

One can notice that some overlapping problems were found. Four problems were found by two evaluators and one problem was found by all three evaluators. However, when problems were considered thematically (instead of specifically), there was larger overlap in evaluations.

Following themes were identified and categorised:

- **C1: Input and output labelling inconsistency.** Input buttons have either icon or number. Output areas display selected input as text. There is inconsistency between icon and textual representation.
- **C2: System state visualisation.** Suggestions were made how to visualise the state of the system so that it is clearer at a glance.
- **C3: Accessibility & visibility issues.** Contrasts etc. are not thought so that the user interface is accessible highly enough by colour blinds.
- **C4: Draggable power button behavior.** Power button drag & drop interaction pattern was not considered familiar.
- **C5: Error prevention feature suggestions.** Feature suggestions to prevent possible mistakes in use.
- **C6: Power user feature suggestions.** Suggestions about features that would make the usability of the system more efficient.
- **C7: General usability issues.** Usability problems that did not fall into any other category.

Problems were assigned to different heuristics as follows. Some problems were assigned under two separate heuristics.

1. Visibility of system status: **5 pcs**
2. Match between system and the real world: **6 pcs**
3. User control and freedom: **1 pcs**
4. Consistency and standards: **6 pcs**
5. Error prevention: **4 pcs**
6. Recognition rather than recall: **5 pcs**
7. Flexibility and efficiency of use: **7 pcs**
8. Aesthetic and minimalist design: **2 pcs**
9. Help users recognise, diagnose, and recover from errors: **0 pcs**

10. Help and documentation: **1 pcs**

Finally, all of the problems were reviewed by the author. Cost to fix the problem was estimated, and based on that and the severity rating of the problem, the feasibility to fix the particular problem was estimated. Comments were also added from the author's point of view. Problems with the highest or second highest estimated feasibility to fix (4 or 5) were as follows:

- **Input and output labelling inconsistency** revised as a whole
- All **accessibility & visibility issues**
- Visualising **turned off displays** differently
- Hiding **draggable power button** when all of the displays are turned off
- Fixing many of the **general usability issues**

Problems and suggestions were combined to a single spreadsheet and numbered (H1...H34). Full list of problems with feasibility estimations and author's comments can be found in section B.3.

4.2.3 Debriefing session

After combining the results, a *debriefing session* (as described by Nielsen 1995) was organised in a WhatsApp group with organiser and all the evaluators. All of the problem lists were posted to the chat as well as combined list of all the problems. A short briefing was given to encourage mention anything that comes into mind about evaluation process or any insights that has popped into mind after evaluation session.

No one of the evaluators did not comment anything, so it can be considered that their voluntary scientific efforts were bounded to the evaluation sessions.

4.3 Results of expert review

Two expert review sessions were conducted in March 2023 and May 2023. User interfaces were reviewed by two experts. Both have been professionally involved in AV system user interface design for 10+ years.

As described in subsection 3.4.3, the process was free-form - not formal or holistic by any means. The use case and conditions of use related to the interface was quickly briefed and after that the tablet interface was shown for participant to explore. The aim was to gather first impressions and suggestions based on their professional experience. Results were then transcribed to next subsections and linked to the results of heuristic evaluation by utilising the same categories presented in subsection 4.2.2

and numbering used in combined problem list (Figure B.5, section 4.4). Newly found suggestions were labeled (*Problem E1...E4*).

4.3.1 Impressions by Reviewer 1

Reviewer 1 evaluated only *Interface 1.* First impression was a question about usage of info screen input button (see *Problem H33*). It was not immediately clear that also buttons outside the rooms are draggable. First thought was that displays are turned off by clicking them (as thought in *Problem H17*). Improvement suggestion was to make draggable items to stand out from the background, f.ex. by applying a drop shadow effect over them (*Problem E1*).

Another impression was that one has to read the text on the output display areas to figure out the applied routings (*Category C2*). Is it certain for the user that for example a screen of a laptop located in this room is not displayed in some another room? Improvement suggestion was to highlight a background of the "input" room with same colour as an "output" room (*Problem E2*). Another idea related to system state visualisation (*Category C2*) was to locate inputs outside of the rooms and move them inside the room after dragged to the output (*Problem E3*). Also, the inconsistency between unlabelled buttons and output area texts (*Category C1*) was noted.

Reviewer 1 pointed out that in a past case there was a carefully implemented option to preview incoming signals to inputs (related to *Problem H14*). However, in user testing they found out that the preview option confused users and slowed down the usage. Reasoning was that the users are not necessary aware of which kind of signal is coming out of their laptop, and at least they do not know which signal is coming out of a screen sharing device. It was noted that option to preview inputs was confusing with such a few as three inputs.

Instead, he suggested to implement a feature that the inputs with incoming signal (a laptop connected to HDMI input or a ClickShare) could be coloured with an indication colour - green, for example (*Problem E4*). That would limit reasonable options and speed up the usage.

Also, *Reviewer 1* noted that dragging touch and feel is solid with iPad touch screen. He would be interested to test that interaction pattern with Crestron panels also.

4.3.2 Impressions by Reviewer 2

Reviewer 2 also evaluated *Interface 1.* His first impression was that it is clear that space-related input buttons are located inside the spaces in the floor plan, and "general" input buttons are located outside of the spaces. Also, initial impression was a clarity in a sense that physical input locations and all of the routing possibilities are visible at a glance. However, it was not initially clear that one can drag inputs from one room to outputs of another room - it took a while to get it figured out.

Reviewer 2 pointed out that assigning one input to all of the outputs (see *Problem H16*) can be a typical usage pattern and implementing it should be considered, even though it is not required in specifications. He also noted that user interface encourages clicking the outputs - it could be considered to add some functionality there (*Problem H17*).

When looking at *Interface 3*, *Reviewer 2* noticed that there is no indication about which program is sent into restaurant (*Problem H21*). Also, he noted the possibility of feedback loop related to program transfer functionality (*Problem H32*).

In general, his impression was that interface is clear and drag & drop works well with iPad - even though the interaction pattern is not his personal favourite when compared to two clicks (*Problem H17* or *Problem H18*).

4.4 Improvement suggestions

In this section the findings and impressions mentioned in previous sections are summarised to provide a bunch of concrete usability improvement actions. The actions are divided into subsections by categorisation and feasibility analysis done in heuristic evaluation (subsection 4.2.2). They are expanded and refined by the impressions noticed in expert reviews (section 4.3). Subsections are ordered so that the most feasible improvement areas are listed first. At every section, there is a short wrap-up and a summarised list(s) of problems and suggestions based on Figure B.5.

4.4.1 Consistency and system state visibility

Consistency issues between input buttons and output area labelings (*Category C1*) were noticed by every heuristic evaluator and expert reviewer. Also, user of *Interface 3* noted that space names should be placed on floor plan to make it clearer to perceive which space is which. Fixing them would provide easy and feasible improvement to perceived usability. Suggestions:

- Use both laptop icon and input name (as displayed in output display area) in draggable HDMI input buttons
- Place room names over layouts

#	Problem / Suggestion	More info	UI	Heuristic	Feasibility
H1	Input icon and display text inconsistency	HDMI input icon has only an image of laptop - display output does not have icon but states "HDMI x" instead	All	4	5
H2	Only number is shown in HDMI input buttons	Laptop icons are clearer and they feel more approachable. Just a plain number requires more prerequisites about the system	2	2	5
H3	User has to remember the room names	Room names are used to indicate input HDMI connector routings in display areas. However the room names are not marked in UI so user has to remember which room is which	3	6	5

Table 4.2 *Problems related to Category C1: Input and output labelling inconsistency*

Also, several improvement suggestions were made how to improve the visualisation of system state. They are listed in *Category C2* and discussed in subsection 4.3.1.

#	Problem / Suggestion	More info	UI	Heuristic	Feasibility
H4	Outputs displays with inputs assigned could have a different colour	It would be a bit easier to see the whole state of the system if output displays with inputs assigned (and therefore turned on) had a different colour	All, esp. 3	1	4
H5	Complete system state is not visualised	One has to read text in all displays and map them to corresponding room to build a mental map of the routings. Could be a problem especially when host is changed during the presentation? Especially problem with UI 3 with many outputs	All, esp. 3	1	2
E2	Visualise room "linking" with a background colour	If input of one room is assigned to output of another room, the backgrounds of the rooms could be coloured with the same colour	1	1	3
E3	Locate input buttons outside of the rooms	Locating input buttons outside of the room and moving them inside the room when assigned to particular output could improve the visualisation of system state	1	1	3
E4	Mark inputs with incoming signal with different colour	Indication colour could be used to indicate inputs with incoming signal / connected device to speed up the input selection	1	1	3

Table 4.3 *Problems related to Category C2: System state visualisation*

4.4.2 Accessibility & visibility

Possible accessibility issues (*Category C3*) were not taken into account at all during the design process. One should utilise testing tools to ensure that user interface is operable by colour blinds also. Also, the colour choices should be revised so that it is easy enough to spot certain user interface elements.

#	Problem / Suggestion	More info	UI	Heuristic	Feasibility
H6	User interface suitability for people with colour blindness	This has not been tested at any point of the development	All	4	5
H7	Contrast in display output area	Contrast between "projector warming up / cooling down" state (light gray) and "projector on/off" state (blue) could be larger	All	1	5
H8	Display indicator line colour	Display indicator is a main element to indicate display position but line colour is barely noticeable	1, 3	4	4
H9	Light blue display indicators missing	No visual clue how displays are arranged (can possibly be noticed in room though)	2	2	4
E1	Make the input buttons appear more draggable	One can make the input buttons to stand out from background, f.ex. by applying a drop shadow effect to them	All	6	4

Table *4.4 Problems related to Category C3: Accessibility & visibility issues*

4.4.3 Other smaller fixes

There were lots of smaller fixes that are feasible to implement listed in categories *C4* and *C7*. One should consider which ones to implement in future implementations of the system.

#	Problem / Suggestion	More info	UI	Heuristic	Feasibility
H10	"Power button" could be hidden when all of the displays are off	Button has no use when all of the displays are off. Could make interface clearer	All	8	5
H11	Displays don't turn on when power button is dragged over them	First idea by instinct is to turn displays on when starting to use the system. There is no point doing that as there would be not any image displayed.	All	2	4
H12	Dragging the power button is not a standard interaction pattern	This was the first time seeing this kind of interaction pattern for turning power on or off. Not an intuitive way. One gets familiar with it quickly, however.	All	4	2

Table *4.5 Problems related to Category C4: Draggable power button behavior*

#	Problem / Suggestion	More info	UI	Heuristic	Feasibility
H23	Feedback when changing a routing	Only feedback is a short pause of movement of icon (in addition to text change). There should be clearer cue that input has changed / action is completed.	All	1	4
H24	Exact input connector location	Input connector locations could me marked more exactly to the layout, so that they would be easier to locate. Especially with Interface 3 with lots of stuff on the screen.	All, esp. 3	2 / 6	4
H25	Camera input button location	Camera is located in space, so the camera input button could be located on floor plan as well as the HDMI inputs	3	2	4
H26	Border around ClickShare buttons	These buttons belong to same group, so they could have border around them in addition to label.	2	6	4
H27	Missing output display area for Space 1	Display indicator (light blue line) is present but output display is missing. This is "last minute" change in UI as projector was removed from the room.	1	2	4
H28	Some of the output display areas are clickable	Some output display areas provide visual feedback when clicked, some not. This is a bug	2, 3	4	4
H29	Slow input icon animation	Input icon animation after dragging (when object returns to position) is too slow. Might be annoying even for users in intermediate level.	All	7	3
H30	Input button can be dropped over multiple outputs	One can drop input button over multiple outputs, and that routes input to both of the outputs. Bug or feature?	3	1	3
H31	Camera input button icon	First impression of camera icon is not a camera	3	4	3
H32	Prevent Restaurant feedback loop	It should not be allowed to drag Restaurant input on main screen when "Send image to restaurant" is selected, as it could cause infinite loop.	3	5	3
H33	"Info screen" button does not give any info about usage of the system	First impression about the button is that it is a help button. One has to know beforehand that system has info screen as input that the button relates to.	1	4, 10	2
H34	"Shut down the system" by accident	Right-handed persons might accidentally press "Shut down the system" button with right wrist when operating the system so that tablet is down at the table	All	5	2

Table 4.6 *Problems related to Category C7: General usability issues*

4.4.4 Interaction pattern improvements and other major fixes

Also, the participants generated ideas about new features and suggestions about new interaction patterns. They are listed in categories *C5* and *C6* as well as discussed in section 4.3. Their feasibility should be carefully considered when making future implementations of the system.

#	Problem / Suggestion	More info	UI	Heuristic	Feasibility
H13	Routings confirmation	Should there be an option to confirm routing changes? Host could move input to wrong output by accident and that could be really awkward if there is some other customer in that room. User can be afraid to use the system if action leads to immediate result and possible problem without confirmation.	All, esp. 1	5	3
H14	Opportunity to preview inputs	One has to route inputs to outputs "blindfolded", as there is no means to preview inputs.	All	5, 6	2
H15	Undo functionality	If there was undo functionality, users could be more confident with the interface.	All	3	2

Table 4.7 *Problems related to Category C5: Error prevention feature suggestions*

#	Problem / Suggestion	More info	UI	Heuristic	Feasibility
H16	ALL button	Would the users need ALL button to assign single input to all displays?	All	7	3
H17	Another option for input selection interaction pattern	There could be possibility to open a list of inputs by touching the output display area.	All	7	2
H18	Yet another option for input selection interaction pattern	Natural interaction pattern could also be clicking input button first and then click output button to assign the routing. If there is need to limit outputs, one could hide the disallowed output buttons	All	7	2
H19	Build-mode	Could there be a "routing editor", where one could do multiple routings and apply as once? On the other hand, applying is extra step so that kind of editor should be used in parallel with current editor.	All, esp. 3	7	2
H20	Efficiency with major routing changes	Some other kind of UI (matrix f. ex.) could be more efficient if there is a need to change multiple routings at once, or change routings frequently	All	7	2
H21	Hiding "Send program to Restaurant"	Could this feature be hidden to some "power user mode" if rarely needed? When selected, the main display could have indication that program is sent to restaurant.	3	8	2
H22	Mirroring outputs	Could one drag output over output to mirror its contents / input assigned to it to another display?	All	7	1

Table 4.8 *Problems related to Category C6: Power user feature suggestions*

5 Discussion

In this chapter, the results presented in chapter 4 are summarised, analysed and discussed. Also, some other aspects noticed during the research will be discussed here.

As defined in section 1.3, this research had three main goals. The first goal was to evaluate the usability of three example interfaces. During the literature review, it was noticed that summative evaluation methods are best suited to evaluate usability of existing interfaces.

The second goal was to find out how to improve the usability in future implementations of this particular type of interface. Again, it was noticed that a cost-effective way to improve the usability is to seek usability problems using formative methods, especially heuristic evaluation.

Third goal was to gain generalisable information about different interaction patterns, so that AV system designers can utilise the insights when choosing suitable patterns for their systems.

5.1 Summative evaluation

It became evident that it is not possible to conduct extensive summative / quantitative measurement or study due to small user base and other limitations summarised in section 3.3. Potential sample size was too small for any valid statistical analysis. However, the questionnaire was still conducted. What can one deduce from the results?

First, all of the current users of the system were highly satisfied to the usability of the system and video matrix control. That is a notable result itself, even though one cannot derive from the result that other users would be as highly satisfied. Additionally, there are some aspects that might cause bias to assessments.

- All the users had been using the system for a while. The questionnaire did not gather information about the learning curve of the system. The pain caused by learning the system might have already been forgotten while users started to get better along with the system. However, when trainings have been given to systems with the same working principle, the initial impressions of easiness and learnability of the system have always been positive. That is something that could have been explored with the questionnaire.

- Even though users of the systems are professionals, they might not be familiar with other AV control systems and therefore they might not be able to compare their experiences to other systems. However, as stated by Mäenpää (interview, 2023), the average usability of an AV control system is not considered very high - therefore, they might rate the usability of evaluated systems high in comparison even though if they are familiar with other systems. That is also something that should have also been addressed in the questionnaire.

Second, information was gained about the usage of the system. It was validated that systems are actually used by hotel personnel - just as it was thought at the design phase of the systems. However, there was some indication that some of the clients are also operating the systems. It could be a subject of additional research to figure out who are the actual (and potential) user groups of the systems and how do they differ from the thoughts and specifications made at design phase of the systems.

If the questionnaire was done with proper sample size, there should have been more attention towards the structure and wording of the questionnaire. As noticed by Hornbæk 2006, questionnaires that focus on evaluating satisfaction of use are quite often formed some non-standard way and are therefore not easily comparable. Using some standard method would make results generally more useful.

5.2 Formative evaluation

Formative part of the study was more comprehensive. The heuristic evaluation combined with expert reviews helped to find out several usability problems and produced feasible improvement suggestions. *Double expertise* was well utilised in both methods.

The heuristic evaluation and the expert review supported each other well. Most of the problems found in expert reviews were also revealed in the heuristic evaluation, but the experts' approach towards the problems and improvement ideas were maybe a bit more practical and feasible. On the other hand, heuristic evaluators found some problems and made observations "out of the AV system design box" that were not noted by experts. It was especially remarkable that the heuristic evaluators noted problems related to accessibility, which should be obvious to avoid in design work.

One impression was that the heuristic evaluators focused on general usability problems at first, but during the evaluation (after the most obvious problems were found) they started to moving towards "power user approach", suggesting features that would make use of the system more efficient. That was not the case in expert reviews. It could be due to that the heuristic evaluators had a conception that users operate the system frequently (being "power users" in that sense). Also, evaluators were highly technically oriented, so it was possible that they suggested features that would fit into that mindset.

Contradictory, the author had a conception that users are more likely "intermediate users" that do not require power user features - added features might make the user interfaces less approachable. This could have been communicated clearer to the evaluators.

However, there is no real evidence how the systems are actually used in this sense. So, even though there was a conception about the context of use of the example system, it was not detailed enough and was based on assumptions. This is also something that should have been inquired in the questionnaire and should possibly be researched later. More discussion about the subject can be found at subsection 5.3.1.

Nielsen's list of heuristic (subsection 2.3.1) seemed to be a good base for evaluation. As reported in subsection 4.2.2, the found usability problems distributed somehow evenly among different heuristics. One can avoid possible validation issues related to a custom, domain-specific heuristic lists (described by Hermawati and Lawson 2016) by utilising widely used and already validated list of heuristic, like Nielsen's.

It was noted during the sessions that there is no clear heuristic for accessibility issues. They can fitted to some of the categories, but definite heuristic for accessibility issues would encourage evaluators to spot that kind of a problems.

Another approach could also have been applied when performing the heuristic evaluation. Harley 2018 mentioned in a description of expert review method that in addition to usability problems, one could gather insights about what is good in the interface regarding the usability. That information could be used when there is reason to make changes to the interface: what should be retained? Also, one could use the insights when marketing the product.

5.3 General results

This research focused on evaluating particular drag & drop interfaces *an sich* - they were not compared to other interfaces. To gain valid information about how drag & drop interaction pattern compares or performs against other ways of implementing an interface, some kind of comparison study about users preferences towards different kinds of interfaces should be conducted.

However, some insights about pros and cons of different interaction patterns were gained during the heuristic evaluations and interviews and could be summarised here.

5.3.1 User levels

During the research activities it was noted that a strong attention should be paid to which kind of users will actually be using the system. In the conducted interviews there were different approaches to loosely categorise the users of AV systems.

C. Lewis et al. 1990 utilise the concept of *walk-up-and-use* interface - that could be used without any prior knowledge about the system. This kind of users could be called as *beginner users*. Another category could be *intermediate users*, which know the prerequisites of the system and who have time and motivation to get familiar with the system - it might be a part of their work to operate the system. Then, there could be *advanced users* (or *power users*, or *technical users*). They might be technically oriented and have in-depth understanding of the system. They want to work efficiently and probably control the deeper details of the system.

Kantoniemi states in interview (2023) that he starts the design process by figuring out who will eventually be using the system and then "putting oneself in their shoes". Main design challenge is that designs that do look perfectly clear and logical to the designer are not necessarily that to the user of the system.

Sivonen (interview, 2023) has the same approach. A design starts by identifying who will be using the system and what are their user levels. Typically users are categorised into two levels: beginner and technical. Beginner-level interfaces are simple, intuitive and as automatised as possible. It then depends on the customer which direction they want - many of them want both, and eventually there will be separate interfaces for beginners and technical users.

Mäenpää (interview, 2023) approaches the issue so that there are typically no separate user levels. The interface should be easy enough to be operated by all kinds of users. Technical users might gain additional control to the system by operating dedicated control interfaces of mixer or audio processor, for example.

In the case of evaluated interfaces, it was identified at the design phase that they will be used by users of intermediate level. Usage of the systems will require some prior knowledge and understanding, but as the users are typically not technically oriented persons, the approach has to be as simple as possible (still implementing all the features required in specifications).

However, an insight was made when conducting the questionnaire: even though the systems were designed to be used by the hotel personnel (intermediate users), they were actually used by the clients (beginner users) at some cases. Could it be reasonable to design the interfaces so that they encourage to be operated by beginner users also - even though it is not necessarily explicitly required? That would extend their usage possibilities and probably ease the daily work of the hotel personnel.

5.3.2 Choosing an interaction pattern to control a video matrix

The choice of underlying AV control system can affect the possible approach for interaction pattern selection. For example, some Crestron tablets are based on touch screen technology that offers uncertain user experience when dragging & dropping (interview with Sivonen, 2023). Also, Crestron components available do not provide possibility for free-form drag & drop (interview with Kantoniemi, 2023).

There are also other aspects steering the interaction pattern choice for input selection. Kantoniemi and Mäenpää (interview, 2023) assess that matrix views are technical and engineer-like per se, and might be frightening for regular users. As discussed in subsection 5.3.1, it might be feasible to create separate interfaces for different user levels. Matrix interface could be used by technically more advanced users who do not get scared about the view.

When considering different interaction patterns presented in subsection 2.1.4, the following observations and reasoning can be done.

Subpages approach aims to create a simple, clean and uncluttered interface. However, the state of the system is divided among the subpages and can not be perceived at a glance. Also, the mappings of inputs and outputs between user interface and real world must be communicated clearly to the user. Subpages approach suits best the situations where there are only one or two outputs and relatively low number of inputs.

List of inputs is a bit similar approach to subpages. It differs mainly so that all of the outputs are located at single page. Therefore, the full state of the system is visible on a single page. However, a list of possible inputs is visible only after clicking an output. Mappings between the system and real world must be considered carefully also here. This approach can be reasonably used with larger number of inputs and outputs when compared to subpages approach.

Using a **matrix view** it is possible to create a view that displays routings of relatively large number of inputs and outputs in a single page. Also, one can easily notice to which outputs a single input is routed. Creating large routings with a matrix view can be really efficient. As stated above, a matrix view can be suitable (and familiar) for technically oriented persons, but it might scare a non-technical user.

Drag & drop over floor plan approach adds some benefits. As the inputs and outputs are placed over a floor plan, the mapping between the user interface and real world becomes more direct compared to approaches listed above. Also, one can see all the possible inputs and outputs at a glance. However, it might be hard to communicate to user if there are limitations in allowed routings such as that some inputs cannot be routed to some outputs. Additionally, this approach may produce a cluttered interface if there are too many inputs and outputs. Largest interface evaluated in this thesis had 7 inputs and 11 outputs, and it did not raise any comments about being too cluttered.

It is also possible to combine the interaction patterns listed above. As suggested in heuristic evaluation (*Problem 17*), one could add a possibility to select inputs also from a list by clicking an output. Also, one could totally discard drag & drop paradigm and operate the interface by clicking, as described in *Problem 18.* Despite of the presence of drag & drop, laying interface to resemble a physical floor plan might help to generate usable interfaces.

5.3.3 Lifespan of an AV system

As mentioned in section 3.1, no comprehensive documentation of the system was provided to the users - instead, a training was organised to get the relevant persons familiar of using the system. People tend to change in organisations - is there a process how the knowledge is transferred to the new employees? Even if there are manuals delivered, they might easily get lost or forgotten. Usability of an AV system can be in such a level that one can learn to operate it without a manual, but typically there are some aspects that are good to be at least discussed.

Additionally, as mentioned by Kantoniemi (interview, 2023), sometimes users struggle daily with aspects or problems in AV systems that could easily be fixed, but there is not necessary any route of communication between users and a system supplier. Typically AV system designers have an idea beforehand about who will be using the system, but the actual situation is rarely validated afterwards.

One way to communicate with users afterwards is to arrange a study like this. However, it is practical only in rare cases. Other methods would be to arrange training for users, f.ex. on the yearly basis. During the training sessions one could gain information who are the actual users of the system and which kind of usage patterns they have. That information can then be utilised when creating new systems or making existing systems more usable.

When AV systems are sold as a service, this kind of training / feedback sessions could be included in yearly/monthly fee. Assumption is that periodical feedback / improvement / training loop with the system designers and users would help to create more sustainable and usable AV systems. This is something that could be researched.

6 Conclusion

The results of the study could be loosely categorised to *internal* and *external*. Results that can be utilised by the designer and that can be beneficial for the AV system supplier (Geomailer Oy) can be considered as internal. Gained information that can be used as a base for future research or utilised by other parties can be comprised as external. However, also internal results can provide meaningful insights for external parties.

First goal of the research was to evaluate the usability of existing interfaces. It was found out that actual users of the systems were really satisfied to the interfaces and to the AV systems in general. However, it was not possible to make any scientifically valid generalisation of the results and therefore the insights can be considered mainly internal.

Second goal was to find out how to improve usability of similar interfaces in the future. This was evaluated by performing heuristic evaluation and expert reviews on the interfaces. This generated lots of valuable insights and suggestions that were organised to make up a feasible improvement plan. Main issues were related to consistency, system state visibility and accessibility. Also, suggestions to smaller fixes and interaction paradigm enhancements were made. Also, this information is mainly internal by nature.

Some general, externally usable insights were also gained. Different interaction patterns and paradigms and their pros and cons were discussed. It seems that the selection of the most meaningful interaction pattern depends highly on the target context of use. Also, the chosen AV control system may add some technical limitations. Drag & drop paradigm raised mixed feelings among evaluators, but in overall the example interfaces were considered clear to use. Comparison studies could be conducted to gain additional information about usability differences of different interaction patterns.

It was noted that when evaluating usability with either summative or formative methods, one should have a clear, validated and detailed conception about the actual context of use. This is something that could be researched in the future. One could gather this kind of information by organising workshops, face to face interviews or observation studies with actual users of the systems. Based on the gained insights, it is recommended that at least some kind of training or communication between users and designer / vendor should be done also after the delivery of an AV system.

Generally, it seems that the AV field could benefit more from the usability research. Currently, the implementation of usability principles is largely based on a personal interest. The usability studies, heuristics and design principles could be used more during a design process. There could be a stronger weight on usability on every phase of the AV system acquisition starting from the requests for quotations.

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A Questionnaire

A.1 Initial questions

The following questionnaire was sent to responsible users of the system via email on *16th of February, 2023.*

```
Hei!

Sain ...:lta yhteystietosi.  Lähestyn teitä koskien Hotelli ...:ssa käytössä
olevaa kokoustilojen (<tila 1>, <tila 2>, <tila 3>, ...)  AV-järjestelmää, jota
olen ollut toteuttamassa.

Teen gradua AV-ohjauslogiikan käytettävyydestä ja haluaisin kuulla lyhyesti
näkemyksenne pariin kysymykseen.  Tämä on samalla hyvä mahdollisuus antaa palautetta
järjestelmästä ja saada parannusta mahdollisiin hankaluuksiin sen käytettävyydessä.
Jos joku toinen henkilö toimii aktiivisemmin järjestelmän parissa, pyytäisin
hänen yhteystietojaan, jotta voin osoittaa kysymykset suoraan hänelle.

Tässä kysymykset lyhykäisyydessään:

1) Ketkä teillä pääasiassa käyttävät järjestelmää?  (esim.  kokousasiakkaat,
talon henkilökunta, ...)

2) Kuinka sujuvaa järjestelmän käyttö on ollut noin yleisesti?  (sana on vapaa)

3) Kuinka sujuvaksi koette kuvalähteiden valinnan (ks.  liite)?  (1=erittäin
hankalaa, 7=erittäin sujuvaa)

4) Tuleeko mieleen mitään kehitysideoita liittyen kuvalähteen valintaan tai
järjestelmään ylipäänsä?  (sana on vapaa)

Kiitos jo etukäteen osallistumisesta ja hyvää loppuviikkoa!

Terv.  Lauri Heikkilä / puhelinnumero
```

<Attached: screenshot of a particular user interface>

A.2 Communication

The answers to the questions are listed here.

A.2.1 User 1

20th of April, 2023

Moi Lauri. Sorry kun unohtui tämä. Kiitos kun muistutit :) ,
Ohessa vastauksia.

1. Järjestelmää käyttää henkilökunta.
2. Hyvin yksinkertainen ja sujuva käyttää
3. Hyvin sujuva. En ainakaan henkilökohtaisesti koe vaikeaksi. eli 7
4. Tällä hetkellä kyseinen järjestelmä toimii hyvin riittävästi noissa kokoustiloissa.

Mukavaa kevätää t.

A.2.2 User 2

20th of February, 2023

Hi Lauri,

I am in charge mostly in our Conference and Meeting side.
Here i will give feedback by answer the questions you sent.
1. In every meeting, we as the house staff are the mainly use the systems. We prepared the systems before our client start their meeting, like lighting, audio, display/projector and microphone.
2. The systems function smoothly. It is easy and simple to navigate event for some of our client who just know about it.
3. And I will give 7 for how easy the system to use.
4. It is very clear and easy to understand.
Please feel free to contact me if you have any more questions or concerns about it.

Best regards,

A.2.3 User 3

6th of March, 2023

Moi!

Lyhyesti ehdin kommentoida alle;

1. Kokoushenkilökunta, asiakkaat vain tarvittaessa. Pyrimme malliin jossa kaikki on asiakkaalle valmiina

2. Suurimmaksi osaksi kaikki on sujunut hyvin.

3. 6

4. Toisinaan isojen tilojen eri näyttöjen käyttöä ja kuvan jakoa helpottaisi jos myös tilan nimi olisi kuvapohjassa, esimerkiksi <tila1> <tila2>. Aina ei ole itsestään selvää, että laite on käyttäjällä edes oikein päin kädessä, jolloin voidaan säätää epähuomiossa myös väärää tilaa.

B Heuristic evaluation

B.1 Briefing document

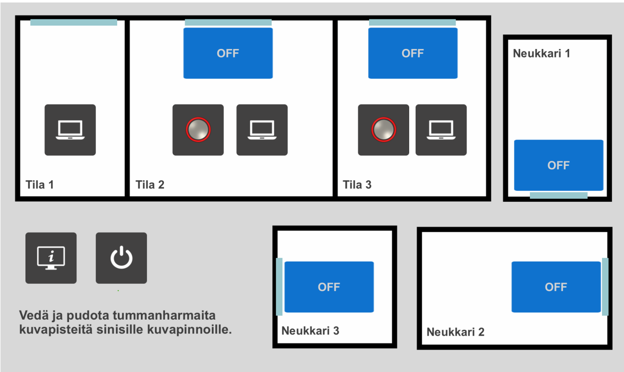
Briefing document handed out to evaluators to provide background information about the process of evaluation and the AV systems in to be evaluated.

Prerequisites

- Focus is to evaluate three interfaces located in hotel conference spaces in Vaasa, Kuopio and Joensuu.
- The interfaces in case are a specific part of AV system user interface. They control *video matrix*, a component which routes video inputs to video outputs.
- Interfaces are operated by specified personell (conference hosts).
- The interfaces are laid out over actual floor plan. Drag & drop is used to route video inputs (HDMI connectors, ClickShare screen sharing devices, video cameras etc.) to specific outputs (projectors or screens).
- The displays (projectors or screens) turn on when an input is dragged over them. They can be turned off by dragging power symbol over them.

Figure B.1 *Heuristic evaluation briefing document*

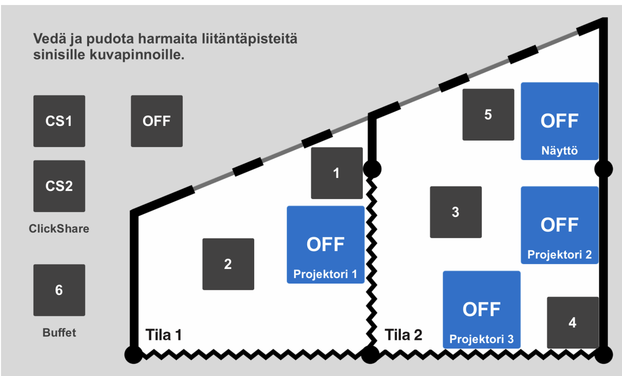
User interface 1



- **Location:** Conference facilities of a hotel located in Kuopio
- **Spaces:** Three combinable spaces & three separate meeting rooms
- **Inputs:** 6 (3x HDMI connectors, 2x ClickShare, 1x Info screen)
- **Outputs:** 5 (2x projector, 3x display)
- Spaces 1, 2 and 3 can be combined or separated with curtains.
- Each space has a HDMI input and two of the spaces have ClickShare screen sharing devices.
- Three fixed meeting rooms can be used individually with remote control or inputs of combinable spaces can be routed to meeting rooms.
- Hotel info screen can also be routed to any display.

Figure B.1 Heuristic evaluation briefing document

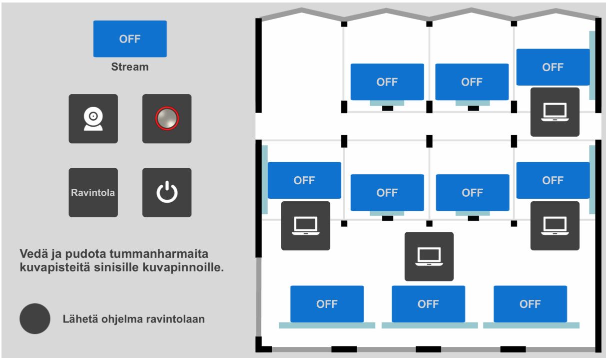
User interface 2



- **Location:** Conference facilities of a hotel located in Vaasa
- **Spaces:** Two combinable spaces
- **Inputs:** 8 (5x HDMI connectors, 2x ClickShare, 1x Buffet HDMI)
- **Outputs:** 5 (3x projector, 1x display)
- Two spaces can be combined with curtains. When separated, they can be controlled by specific user interface that affects only that space. When combined, this interface is used for input and output routing.
- There are five numbered HDMI input connectors located in the space. They are positioned physically as located in the interface. One HDMI connector (Buffet) is physically located outside the area. Additionally, there are two ClickShare screen sharing devices that can be routed to outputs.
- Space 1 has a single projector. Space 2 has two projectors and one display. Projectors and displays power on automatically when an input is dragged over them. They can be powered off manually by dragging the power symbol over them.

Figure B.1 Heuristic evaluation briefing document

User interface 3



- **Location:** Conference facilities of a hotel located in Joensuu, Finland
- **Spaces:** Eight combinable spaces
- **Inputs:** 7 (4x HDMI, 1x ClickShare, 1x Camera, 1x Restaurant)
- **Outputs:** 11 (6x projector, 4x display, 1x stream)
- Hotel conference facilities consist of eight different spaces that can be combined or separated with curtains multiple ways. Each allowed combination has a dedicated interface.
- This particular interface is for the combination where all of the curtains are open and the whole space is combined to a single area.
- There are six projectors and four displays in the area. Also, any input can be routed to a streaming device.
- Four HDMI connectors, ClickShare screen sharing device, video camera and program feed from the restaurant building can be used as inputs. Also, the input routed to the main projector can be fed to restaurant building to be used as an input there.

Figure B.1 *Heuristic evaluation briefing document*

B.2 Evaluation results (separated)

Problem	More info	How to fix?	Relates to UI	Heuristic	Severity (1-5)
Displays don't turn on when power button is dragged over them	First idea by instinct is to turn displays on when starting to use the system.	There is no point doing that as there would be not any image displayed	All	2 (Match between system and the real world)	1
System state is not visualized	One has to read text in all displays and map them to corresponding room to build a mental map of the routings. Could be a problem especially when host is changed during the presentation? Especially problem with UI with multiple outputs	Some kind of "connection lines" between inputs and outputs?	All, esp. UI 3	1 (Visibility of system status)	4
Routings confirmation	Should there be an option to confirm routing changes? Host could move input to wrong output by accident and that could be really awkward if there is some other customer in that room. User can be afraid to use the system if action leads to immediate result and possible problem without confirmation.	Option 1 - Apply: first change the routings and then select "apply" to apply all the routings at once Option 2 - Confirm: confirm all routing changes, or confirm routing changes if input of one room is routed to input of another room	All, esp. UI 1	5 (Error prevention)	4
Input icon and display text inconsistency	HDMI input icon has an image of laptop, display output does not have icon but states HDMI x	Use similar icons in outputs or add same text to input button which is used in outputs	All, esp. UI 1 & 3	4 (Consistency and standards)	3
Feedback when changing a routing	Only feedback is that text changes in output display area	There could be some stronger feedback to indicate succesful routing change	All	1 (Visibility of system status)	2
Efficiency with major routing changes	Some other kind of UI (matrix f. ex.) could be more efficient if there is a need to change multiple routings at once, or change routings frequently	Option to have another kind of UI for advanced users	All	7 (Flexibility and efficiency of use)	2
Slow input icon animation	Input icon animation after dragging, when object returns to position, is a bit slow	Make animation faster (if possible with the control system used)	All	7 (Flexibility and efficiency of use)	2
User has to remember the room names	Room names are used to indicate input HDMI connector routings in display areas. However the room names are not marked in UI so user has to remember which room is which.	Place room names to UI	UI 3	6 (Recognition rather than recall)	3

Figure B.2 *Heuristic evaluation results (evaluator 1)*

Problem	More info	How to fix?	Relates to UI	Heuristic	Severity (1-5)
"Info screen" button does not give any info about usage of the system	First impression about the button is that it is a help button. One has to know beforehand that system has info screen as input that the button relates to.	Using clearer icon or textual description	1	4 (Standards) & 10 ([lack of] Help & Documentation)	1
Slow input icon animation	Input icon animation after dragging, when object returns to position, is too slow. Might be annoying even in intermediate level	Make animation faster (if possible with the control system used)	All	7 (Flexibility and efficiency of use)	3
Dragging the power button is not a standard interaction pattern	This was the first time seeing this kind of interaction pattern for turning power on or off. One gets familiar with it quickly, however	Figure out another interaction for power off	All	4 (Standards)	2
Feedback when changing a routing	Only feedback is a short pause of movement of icon (in addition to text change)	There could be some stronger feedback to indicate succesful routing change	All	1 (Visibility of system status)	2
Opportunity to preview inputs	One has to route inputs to outputs "blindfolded", as there is no means to preview inputs.	For example, inputs could be previewed by touching & holding the input icon.	All	5 (Error prevention) & 6 (Recognition)	3
Another option for selecting input	There could be possiblity to open a list of inputs by touching the output display area.	Implementing such a feature	All	7 (Efficiency)	3
User interface suitability for people with color blindness	This has not been tested at any point of the development.	There are testing tools available. Test interface with tools and fix if necessary.	All	4 (Standards)	1 or 4
No undo functionality	If there was undo functionality, users could be more confident with the interface.	Implement undo functionality	All	3 (User control and freedom)	2
Only number visible in HDMI input buttons	Laptop icon feels more approachable. Just a plain number requires more prerequisities about the system.	Using inputs with icon and number	2	2 (Match between system and the real world)	3
Input button can be dropped over multiple outputs	One can drop input button over multiple outputs, and that routes input to both of the outputs. Bug or feature?	"Feature", but can be avoided by moving inputs farther from each other	3	1 (Visibility)	2
Build-mode	Could there be a "routing editor", where one could do multiple routings and apply as once? On the other hand, applying is extra step so that kind of editor should be used in parallel with current editor.	Implement "build-mode" editor	All, esp. 3	7 (Efficiency)	2

Other impressions

Focus on user levels. This user interface approach is intended for beginner-intermediate users. Should there be additional, more efficient modes for advanced users?

"Over floor plan" approach is very good.

Figure B.3 *Heuristic evaluation results (evaluator 2)*

Problem / Improvement suggestion	More info	How to fix?	Relates to UI	Heuristic	Severity (1-5)
Missing output display area for Utu 1 room	Display indicator (light blue line) is present but output display is missing. This is "last minute" change in UI as projector was removed from the room.	Clearer indication about missing projector and/or remove display indicator line	1	2 (Match between system and the real world)	3
"Power button" could be hidden when all of the displays are off	Button has no use when all of the displays are off. Could make interface clearer	Hide or disable power button when all of the displays are off	All	8 (Minimalist design)	1
Feedback when changing a routing	After dropping there should be clearer cue that input has changed / action is completed	There could be some stronger feedback to indicate succesful routing change	All	1 (Visibility of system status)	3
Contrast issue in display output area	Contrast between "projector warming up / cooling down" state (light gray) and "projector on/off" state (blue) could be larger	Increase contrast of these two colors	All	1 (Visibility of system status)	2
Input buttons and output area texts do not match	Output areas say f.ex. HDMI or CS, inputs have icons only.	Add corresponding texts to input buttons	All	4 (Consistency)	3
Dragging the power button is not intuitive	Not an intuitive way to turn off the displays	Figure out another interaction pattern	All	4 (Standards)	2
"Shut down the system" by accident	Right-handed persons might accidentally press "Shut down the system" button with right wrist when operating the system so that tablet is down at the table	Figure out another location to the power off button	All	5 (Error prevention)	4
Display indicator line color	Display indicator is a main element to indicate diplay position but line color is barely noticeable.	Figure out other color / other kind of element for indication	1 & 3	4 (Standards) / 6 (Recognition rather than recall)	2
Input numbers are distracting	Laptop icons are clearer. Best would be laptop icon + HDMI + number	Implement as described	2	4 (Consistency)	3
Light blue display indicators missing	No visual clue how displays are arranged (can possibly be noticed in room though)	Add display indicators	2	2 (Match between system and the real world) & 6 (Recognition)	2
Some of the output display areas are clickable	Some output display areas provide visual feedback when clicked, some not. This is a bug	Fix the bug	2, 3	4 (Consistency)	2
Border around ClickShare buttons	These buttons belong to same group, so they could have border around them in addition to label.	Add a border	2	6 (Recognition)	2
Exact input connector location	Input connector locations could me marked more exactly to the layout, so that they would be easier to locate. Especially with Interface 3 with lots of stuff on the screen.	Add visual cues for exact location to the layout	All, esp. 3	2 (Match between system and the real world) / 6 (Recognition)	3
Camera input button icon	First impression of camera icon is not a camera	Find a better icon	3	4 (Standards)	4
Camera input button location	Camera is located in space, so the camera input button could be located on floor plan as well as the HDMI inputs	Relocate camera input button	3	2 (Match between system and the real world)	4
Prevent Restaurant feedback loop	It should not be allowed to drag Restaurant input on main screen when "Send image to restaurant" is selected, as it could cause infinite loop.	Disallow dragging when "Send image to restaurant" is selected	3	5 (Error prevention)	4
Outputs displays with inputs assigned could have a different color	It would be a bit easier to see the whole state of the system if output displays with inputs assigned (and therefore turned on) had a different color	Add different color	All, esp. 3	1 (Visibility of system status)	4
Hiding "Send program to Restaurant"	Could this feature be hidden to some "power user mode" if rarely needed? When selected, the main display could have indication that program is sent to restaurant.				
Is it necessary to use drag & drop interaction pattern?	Natural interaction pattern could also be clicking input button first and then click output button to assign the routing. If there is need to limit outputs, one could hide the disallowed output buttons				
Mirroring outputs	Could one drag output over output to mirror its contents / input assigned to it to another display?				

Figure B.4 *Heuristic evaluation results (evaluator 3*

ALL button	Would the users need ALL button to assign single input to all displays?

Other impressions

Good interface if dedicated to specified group of users and there are no more input/output elements that this

Figure B.4 *Heuristic evaluation results (evaluator 3)*

B.3 Evaluation results (combined)

#	Problem / improvement suggestion	More info	How to fix?	Relates to UI	Heuristic	Severity (1-5)	Found by 1	Found by 2	Found by 3	Expense (1-5)	Feasibility (1-5)	Author comments
C1	**Input and output labeling inconsistency**					**3**	**x**	**x**	**x**	**1**	**5**	This is definitely something that should be fixed to add clearness and consistency. Highly feasible.
H1	Input icon and display text inconsistency	HDMI input icon has only an image of laptop - display output does not have icon but states "HDMI x" instead	Use similar icons in outputs and/or add same text to input button which is used in outputs	All	4 (Consistency and standards)	3	x		x			
H2	Only number is shown in HDMI input buttons	Laptop icons are clearer and they feel more approachable. Just a plain number requires more prerequisities about the system.	Use inputs with both icon and number and possibly the word "HDMI"	2	2 (Match between system and the real world)	3		x	x			
H3	User has to remember the room names	Room names are used to indicate input HDMI connector routings in display areas. However the room names are not marked in UI so user has to remember which room is which.	Place room names to UI	3	6 (Recognition rather than recall)	3	x					
C2	**System state visualization**											
H4	Outputs displays with inputs assigned could have a different color	It would be a bit easier to see the whole state of the system if output displays with inputs assigned (and therefore turned on) had a different color	Add different color for shutted down outputs	All, esp. 3	1 (Visibility of system status)	4			x	2	4	Adds one more color to output display areas. Could make interface more restless. If possible to avoid that, very feasible.
H5	Complete system state is not visualized	One has to read text in all displays and map them to corresponding room to build a mental map of the routings. Could be a problem especially when host is changed during the presentation? Especially problem with UI 3 with many outputs	Some kind of "connection lines" between connected inputs and outputs? Could be turned on/off from a button?	All, esp. UI 3	1 (Visibility of system status)	4	x			4	2	Could clutter the interface. Making input and output labeling consistent may make the situation clearer?
C3	**Accessibility & visibility issues**											
H6	User interface suitability for people with color blindness	This has not been tested at any point of the development.	There are testing tools available. Test interface with tools and fix if necessary.	All	4 (Standards)	dep.		x		1	5	Should definitely run testing tools for the interface
H7	Contrast in display output area	Contrast between "projector warming up / cooling down" state (light gray) and "projector on/off" state (blue) could be larger	Increase contrast of these two colors	All	1 (Visibility of system status)	2			x	1	5	Related to above
H8	Display indicator line color	Display indicator is a main element to indicate diplay position but line color is barely noticeable.	Figure out other color / other kind of element for indication	1 & 3	4 (Standards) / 6 (Recognition rather than recall)	2			x	1	4	Could be easily fixed, should be fixed
H9	Light blue display indicators missing	No visual clue how displays are arranged (can possibly be noticed in room though)	Add display indicators	2	2 (Match between system and the real world) & 6 (Recognition)	2			x	1	4	Should be fixed if there will be changes in interface
C4	**Draggable power button behavior**											
H10	"Power button" could be hidden when all of the displays are off	Button has no use when all of the displays are off. Could make interface clearer	Hide or disable power button when all of the displays are off	All	8 (Minimalist design)	1			x	2	5	Could be easily changed
H11	Displays don't turn on when power button is dragged over them	First idea by instinct is to turn displays on when starting to use the system. There is no point doing that as there would be not any image displayed.	Hide or disable power button when all of the displays are off	All	2 (Match between system and the real world)	1	x			1	4	Fixing above would prevent this
H12	Dragging the power button is not a standard interaction pattern	This was the first time seeing this kind of interaction pattern for turning power on or off. Not an intuitive way. One gets familiar with it quickly, however.	Figure out another interaction to power off the displays	All	4 (Standards)	2		x	x	?	2	Changing this pattern would require other changes in interaction patterns (see below). Could be feasible depending on the feasibility of the new pattern. However, dedicated users will most likely get used to this pattern.
C5	**Error prevention feature suggestions**											
H13	Routings confirmation	Should there be an option to confirm routing changes? Host could move input to wrong output by accident and that could be really awkward if there is some other customer in that room. User can be afraid to use the system if action leads to immediate result and possible problem without confirmation.	Option 1 - Apply: first change the routings and then select "apply" to apply all the routings at once Option 2 - Confirm: confirm all routing changes, or confirm routing changes if input of one room is routed to input of another room	All, esp. UI 1	5 (Error prevention)	4	x			3	3	Can prevent errors, but can also make the usage of the system less efficient. Should be discussed with every client that is there any "risk possibilities" that would require this kind of option.
H14	Opportunity to preview inputs	One has to route inputs to outputs "blindfolded", as there is no means to preview inputs.	For example, inputs could be previewed by touching & holding the input icon.	All	5 (Error prevention) & 6 (Recognition)	3		x		4	2	Might be to costly to implemented due to technical constraints
H15	Undo functionality	If there was undo functionality, users could be more confident with the interface.	Implement undo functionality	All	3 (User control and freedom)	2		x		4	2	Standard feature in software products, but not very typical in AV control systems. Feasibility should be considered

Figure B.5 *Heuristic evaluation results (combined)*

	Problem / improvement suggestion	More info	How to fix?	Relates to UI	Heuristic	Severity (1-5)	Found by 1	Found by 2	Found by 3	Expense (1-5)	Feasibility (1-5)	Author comments
C6	**Power user feature suggestions**											
H16	ALL button	Would the users need ALL button to assign single input to all displays?	Implementing such a feature	All	7 (Efficiency)				x	2	3	Implemented to some interfaces when required. However, left out when not required, to make the system simpler. Implementation should be considered with client case by case.
H17	Another option for input selection interaction pattern	There could be possiblity to open a list of inputs by touching the output display area.	Could also be implemented side by side to drag & drop pattern	All	7 (Efficiency)	3		x		4	2	Adding another interaction patterns could make using the interfaces more versatile and natural to use. However, can be hard due to limitations of the control system and therefore implementation may not be feasible.
H18	Yet another option for input selection interaction pattern	Natural interaction pattern could also be clicking input button first and then click output button to assign the routing. If there is need to limit outputs, one could hide the disallowed output buttons	Could also be implemented also side by side to drag & drop pattern	All	7 (Efficiency)				x	4	2	Same as above
H19	Build-mode	Could there be a "routing editor", where one could do multiple routings and apply as once? On the other hand, applying is extra step so that kind of editor should be used in parallel with current editor.	Implement "build-mode" editor	All, esp. 3	7 (Efficiency)	2		x		5	2	Costly to implement. May be benefical in some use cases.
H20	Efficiency with major routing changes	Some other kind of UI (matrix f. ex.) could be more efficient if there is a need to change multiple routings at once, or change routings frequently	Option to have another kind of UI for advanced users	All	7 (Flexibility and efficiency of use)	2	x			5	2	Costly to implement. May be benefical in some use cases.
H21	Hiding "Send program to Restaurant"	Could this feature be hidden to some "power user mode" if rarely needed? When selected, the main display could have indication that program is sent to restaurant.	Implementing such a feature	3	8 (Minimalist design)				x	4	2	Adding sub-page for this single feature makes it maybe not that feasible.
H22	Mirroring outputs	Could one drag output over output to mirror its contents / input assigned to it to another display?	Implementing such a feature	All	7 (Efficiency)				x	4	1	"Nice to have" option, but adds quite much complexicity in control system level that makes implementation not very feasible.
C7	**General usability issues**											
H23	Feedback when changing a routing	Only feedback is a short pause of movement of icon (in addition to text change). There should be clearer cue that input has changed / action is completed.	There could be some stronger feedback to indicate succesful routing change	All	1 (Visibility of system status)	3	x	x	x	2	4	Should figure out additional feedback.
H24	Exact input connector location	Input connector locations could me marked more exactly to the layout, so that they would be easier to locate. Especially with Interface 3 with lots of stuff on the screen.	Add visual cues for exact location to the layout	All, esp. 3	2 (Match between system and the real world) / 6 (Recognition)	3			x	2	4	Should figure out a way to implement this without cluttering the interface.
H25	Camera input button location	Camera is located in space, so the camera input button could be located on floor plan as well as the HDMI inputs	Relocate camera input button	3	2 (Match between system and the real world)	4			x	1	4	Camera location was not known at the date interface was made. Should be implemented.
H26	Border around ClickShare buttons	These buttons belong to same group, so they could have border around them in addition to label.	Add a border	2	6 (Recognition)	2			x	1	4	Small thing but easy to fix, would make general impression better
H27	Missing output display area for Space 1	Display indicator (light blue line) is present but output display is missing. This is "last minute" change in UI as projector was removed from the room.	Clearer indication about missing projector and/or remove display indicator line	1	2 (Match between system and the real world)	3			x	1	4	At least display indicator should be removed.
H28	Some of the output display areas are clickable	Some output display areas provide visual feedback when clicked, some not. This is a bug	Fix the bug	2, 3	4 (Consistency)	2			x	1	4	Minor thing, but should be fixed.
H29	Slow input icon animation	Input icon animation after dragging (when object returns to position) is too slow. Might be annoying even for users in intermediate level.	Make animation faster (if possible with the control system used)	All	7 (Flexibility and efficiency of use)	2.5	x	x		2	3	It is not possible to adjust feedback return speed in control system. However, could add control system developer to make the speed adjustable.
H30	Input button can be dropped over multiple outputs	One can drop input button over multiple outputs, and that routes input to both of the outputs. Bug or feature?	"Feature", but can be avoided by moving inputs farther from each other	3	1 (Visibility)	2		x		1	3	Having input areas as large as possible increases usability. However, can be changed if noted as problem for actual users.
H31	Camera input button icon	First impression of camera icon is not a camera	Find a better icon	3	4 (Standards)	4			x	1	3	Could be changed to be more "camera-like". However, current icon is quite close to typical web camera icon
H32	Prevent Restaurant feedback loop	It should not be allowed to drag Restaurant input on main screen when "Send image to restaurant" is selected, as it could cause infinite loop.	Disallow dragging when "Send image to restaurant" is selected	3	5 (Error prevention)	4			x	2	3	Rare situation, but something that should have been prepared for.
H33	"Info screen" button does not give any info about usage of the system	First impression about the button is that it is a help button. One has to know beforehand that system has info screen as input that the button relates to.	Using clearer icon or textual description	1	4 (Standards) & 10 ([lack of] Help & Documentation)	1		x		2	2	If the info screen icon is clear for the actual users of the system, no need to replace it because of the first impression
H34	"Shut down the system" by accident	Right-handed persons might accidentally press "Shut down the system" button with right wrist when operating the system so that tablet is down at the table	Figure out another location to the power off button	All	5 (Error prevention)	4			x	3	2	Think that this is not a problem with wall mounts or cases, which are used in all locations. However, should be checed in every use case.

Figure B.5 *Heuristic evaluation results (combined)*

C Credits

Figure 2.1 (Example system diagram of a small AV system (©Geomailer Oy))
Designer: Lauri Heikkilä
AV system implementation by Geomailer Oy

Figure 2.2 (Subpages interface (Ylä-Savon Sote, ©Geomailer Oy))
Location: Ylä-Savon Sote, Iisalmi
Design tool: DemoPad Designer
AV matrix: Blustream
Design and UI implementation: Lauri Heikkilä
AV system implementation by Geomailer Oy

Figure 2.3 (List of inputs interface (Siun Sote, ©Paisma avoin yhtiö))
Location: Siun Sote, Joensuu
Design tool: Hipaisu UI tool
AV matrix: Kramer
Design and UI implementation: Maaret Saarela / Paiste Mäenpää
AV system implementation by Paisma avoin yhtiö

Figure 2.4 (Matrix view interface (Musiikkimuseo Fame, ©Audico Systems Oy))
Location: Musiikkimuseo Fame
Design tool: Q-Sys Designer
AVoIP matrix: Visionary Solutions
Designer: Janne Sivonen
UI implementation: Hans Ekman
AV system implementation by Audico Systems Oy (Ex-Bright Sales & Installation Oy)

Figure 2.5 (Drag & drop interface (©Blustream Ltd))
AV matrix: Blustream
UI: Blustream web management user interface

Figure 2.6 (Drag & drop over floor plan interface (©Geomailer Oy)) and
Figure 3.1 (Interface 1 (©Geomailer Oy))
Location: Sokos Hotel Puijonsarvi, Kuopio
Design tool: DemoPad Designer
AV matrix: Blustream
Design and UI implementation: Lauri Heikkilä
AV system implementation by Geomailer Oy

Figure 3.2 (Interface 2 (©Geomailer Oy))
Location: Scandic Vaasa, Vaasa
Design tool: DemoPad Designer
AV matrix: Blustream
Design and UI implementation: Lauri Heikkilä
AV system implementation by Geomailer Oy

Figure 3.3 (Interface 3 (©Geomailer Oy))
Location: Sokos Hotel Kimmel, Joensuu
Design tool: DemoPad Designer
AVoIP matrix: Blustream
Design and UI implementation: Lauri Heikkilä
AV system implementation by Geomailer Oy